12 Pelagic Shelf Rockfish

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12.0 Executive Summary

We continue to recommend using the average of exploitable biomass from the three most recent trawl surveys to determine the ABC's for dark, widow, and yellowtail rockfishes. For the three species, the average exploitable biomass from the 2001, 2003, and 2005 surveys was 10,493 mt (8,301 mt for dark rockfish, 168 mt for widow rockfish, and 2,024 mt for yellowtail rockfish). The 2006 recommended ABC for dark, widow, and yellowtail rockfish combined is 551 mt based on tier 5 calculations (F=0.75M). The OFL (F=M=0.07) for dark, widow, and yellowtail rockfish is 735 mt. Recommended area apportionments of ABC dark, widow, and yellowtail rockfish are 146 mt for the Western area, 331 mt for the Central area, 30 mt for the West Yakutat area, and 44 mt for the Southeast/Outside area.

In 2003 for dusky rockfish, the age-structured model was first accepted as an alternative to average trawl survey biomass estimates and was used to determine the ABC. We continue to use the generic rockfish model as the primary assessment tool. This model was developed in a workshop held at the Auke Bay Laboratory in February 2001, and refined to its current configuration in 2004. The model was constructed with AD Model Builder software. The model is a separable age-structured model with allowance for size composition data that is adaptable to several rockfish species. The model's starting point is 1977 and contains all available data including catch, fishery age and size compositions, survey age and size compositions, and survey biomass estimates. The maximum allowable ABC is 4,885 mt based on tier 3 and derived from the recommended model (Model 2).This ABC is about 20% higher than last year's ABC of 4,056 mt. The increase in ABC is likely due to a 2.5 fold increase in survey biomass from 2003 to 2005. The 2006 OFL for dusky rockfish is 5,927 mt. Recommended area apportionments of ABC are 1,292 mt for the Western area, 2,931 mt for the Central area, 270 mt for the West Yakutat area, and 391 mt for the Southeast/Outside area.

For the pelagic shelf rockfish assemblage, ABC and OFL for dusky rockfish are combined with ABC and OFL for dark, widow, and yellowtail rockfish. The 2006 recommended ABC for pelagic shelf rockfish is 5,436 mt with area apportionments of 1,438 mt for the Western area, 3,262 mt for the Central area, 301 mt for the West Yakutat area, and 436 mt for the Southeast/Outside area. The 2006 OFL for pelagic shelf rockfish is 6,662 mt. The stock is not overfished, nor is it approaching overfishing status. A summary table of the exploitable biomass, exploitation rates, ABC, OFL, and natural mortality rate (M) for pelagic shelf rockfish is presented below:

Species	Other Pelagic Rockfish	Dusky Rockfish	2006 Pelagic Shelf Rockfish	2007* Assemblage
Exploitable Biomass (mt)	10,493	49,829	60,322	-
Maximum Allowable F_{ABC}	0.0525	0.088	-	-
Recommended F_{ABC}	0.0525	0.088	-	-
F_{OFL} ($F_{35\%}$)	0.07	0.108	-	-
ABC (mt)	**551**	**4,885**	**5,436**	**5,530**
OFL (mt)	735	5,927	6,662	6,779

*The 2007 ABC and OFL for dusky rockfish were projected using an expected catch value of 2,649 mt for 2006. This estimate is based on recent ratios of catch to maximum permissible ABC. The Author's F method was used for this projection (Table 12-9) in response to management requests for a more accurate one-year projection. These values were added to the projected 2007 ABC and OFL for other pelagic rockfish (rolled over from 2006) to derive the 2007 pelagic shelf rockfish ABC and OFL.

Summary of Major Changes to Model, Data, and Results

New data for 2005 includes 2004 fishery ages, 2005 fishery lengths, updated 2004 fishery catch, estimated 2005 fishery catch, and 2005 survey biomass estimates. We have also updated the size-age matrix with all available age data.

Prior to this year dark rockfish and dusky rockfish were considered one species and treated as a tier 4 species because of the information available for dusky rockfish. Since dusky rockfish now have an age-structured model and are managed as a tier 3 species, we now consider dark rockfish a tier 5 species along with widow and yellowtail rockfish. The exploitable biomass was substantially higher in 2005 for dark rockfish because of an unusually high biomass estimate from the 2005 trawl survey. Conversely, yellowtail biomass estimates were much lower in 2005 because the 1999 survey biomass was exceptionally high and is no longer used in the exploitable biomass calculations.

For dusky rockfish, we provide results from two separate age-structured models. A large amount of age data is now available for dusky rockfish which allows for some relaxation of restrictions on estimating the recruitment standard deviation, σ_r. Model 1 is the same as last year's author recommended model with updated fishery and survey data. Model 2 incorporates a variety of changes, such as using an updated size-age matrix, removing fishery size compositions from 1990 (experimental year for Observer program), full estimation of the recruitment standard deviation and survey catchability, and modifying the natural mortality to be more in line with other similarly aged rockfish. We recommend the use of Model 3 for determining ABC because it uses a more realistic estimate of natural mortality, has a better fit to available data, and closely follows survey biomass estimates.

Responses to SSC Comments

The SSC expressed general considerations for Gulf of Alaska rockfish in regards to the "F40 report" by Goodman et al. (2002). We provide the results of several short analyses that address age truncation of dusky rockfish (see section 12.2.4) and localized depletion of dusky rockfish in the Gulf of Alaska (see section 12.2.5)

12.1 INTRODUCTION

12.1.1 Distribution and life history

The pelagic shelf rockfish assemblage in the Gulf of Alaska is comprised of four species: dusky rockfish (*Sebastes variabilis*), dark rockfish (*S. ciliatus*), yellowtail rockfish (*S. flavidus*), and widow rockfish (*S. entomelas*). The forms of dusky rockfish commonly recognized as "light dusky rockfish" and "dark dusky rockfish" are now officially recognized as two species (Orr and Blackburn 2004). *S. ciliatus* applies to the dark shallow-water species with a common name dark rockfish, and *S. variabilis* applies to variably colored deeper-water species with a common name dusky rockfish.

Gulf-wide, dusky rockfish are the most abundant species in the assemblage, whereas yellowtail, dark, and widow rockfish make up a very small proportion of the assemblage in Alaska waters. Dusky rockfish has one of the most northerly distributions of all rockfish species in the Pacific. It ranges from southern British Columbia north to the Bering Sea and west to Hokkaido Is., Japan, but appears to be abundant only in the Gulf of Alaska.

Adult dusky rockfish are concentrated on offshore banks and near gullies on the outer continental shelf at depths of 100 to 200 m (Reuter 1999). Anecdotal evidence from fishermen and from biologists on the trawl surveys suggests that dusky rockfish are often caught in association with a hard, rocky bottom on these banks or gullies. Also, during submersible dives on the outer shelf of the eastern GOA, dusky rockfish were observed in association with rocky habitats and in areas with extensive sponge beds where adults were seen resting in large vase sponges[1]. A separate study counted eighty-two juvenile red rockfish closely associated with boulders that had attached sponges. No rockfish were observed near boulders without sponges (Freese and Wing 2003). Another study using a submersible in the eastern GOA observed small dusky rockfish associated with *Primnoa* spp. corals (Krieger and Wing 2002).

Parturition is believed to occur in the spring, based on observation of ripe females sampled on a research cruise in April 2001 in the central Gulf of Alaska. Similar to all other species of *Sebastes*, the egg stage is completed inside the female. The larval stage is pelagic, but larval studies are hindered by the fact that the larvae can only be positively identified by genetic analysis. Post-larval dusky rockfish have not been identified; however, the post-larval stage for other *Sebastes* is pelagic, so it is also likely to be pelagic for dusky rockfish. The habitat of young juveniles is completely unknown. At some point they are assumed to migrate to the bottom and take up a demersal existence, juveniles less than 25 cm fork length are infrequently caught in bottom trawl surveys (Clausen et al. 2002) or with other sampling gear. Older juveniles have been taken only infrequently in the trawl surveys, but when caught are often found at more inshore and shallower locations that adults. The major prey of adult dusky rockfish appears to be euphausiids, based on the limited food information available for this species (Yang 1993).

The evolutionary strategy of spreading reproductive output over many years is a way of ensuring some reproductive success through long periods of poor larval survival (Leaman and Beamish 1984). Fishing generally selectively removes the older and faster-growing portion of the population. If there is a distinct evolutionary advantage of retaining the oldest fish in the population, either because of higher fecundity or because of different spawning times, age-truncation could be ruinous to a population with highly episodic recruitment like rockfish (Longhurst 2002). Recent work on black rockfish (*S. melanops*) has shown that larval survival may be dramatically higher from older female spawners (Berkeley et al. 2004, Bobko and Berkeley 2004). The black rockfish population has shown a distinct downward trend in age-structure in recent fishery samples off the West Coast of North America, raising concerns about whether these are general results for most rockfish. De Bruin et al. (2004) examined Pacific ocean perch (*S. alutus*) and rougheye rockfish (*S. aleutianus*) for senescence in reproductive activity of older fish and found that oogenesis continues at advanced ages. Leaman (1991) showed that older individuals have slightly higher egg dry weight than their middle-aged counterparts. Such relationships have not yet been determined to exist for dusky rockfish in Alaska. Stock assessments for Alaska groundfish have assumed that the reproductive success of mature fish is independent of age.

12.1.2 Management measures

This assemblage is one of three management groups for *Sebastes* in the Gulf which were implemented in 1988 by the North Pacific Fishery Management Council (NPFMC). Pelagic shelf rockfish can be defined as those species of *Sebastes* that inhabit waters of the continental shelf of the Gulf of Alaska, and that typically exhibit midwater, schooling behavior.

Until 1998, black rockfish (*S. melanops*) and blue rockfish (*S. mystinus*) were also included in the assemblage. However, in April 1998, a NPFMC Gulf of Alaska Fishery Management Plan amendment

[1]V.M. O'Connell, Alaska Dept. of Fish and Game, 304 Lake St., Sitka, AK 99835. Pers. commun. July 1997.

went into effect that removed these two species from the federal management plan and transferred their jurisdiction to the state of Alaska.

In 2003 for dusky rockfish, an age-structured model was first accepted as an alternative to average trawl survey biomass estimates and was used to determine the ABC. For yellowtail, dark, and widow rockfishes we continue to recommend using the average of exploitable biomass from the three most recent trawl surveys to determine the ABCs.

For dusky rockfish, we continue to use the generic rockfish model as the primary assessment tool. This model was developed in a workshop held at the Auke Bay Laboratory in February 2001, and refined to its current configuration in 2004. The model was constructed with AD Model Builder software. The model is a separable age-structured model with allowance for size composition data that is adaptable to several rockfish species. The model's starting point is 1977 and contains all available data including catch, fishery age and size compositions, survey age and size compositions, and survey biomass estimates.

In 1998, Amendment 41 was passed (became effective in 2000), which prohibited trawling in the Eastern Gulf east of 140 degrees W. longitude. This had important management concerns for most rockfish species, including the pelagic shelf management assemblage, because the majority of the quota is caught by the trawl fishery. Since 1999, the NPFMC has divided the Eastern Gulf management area into two smaller areas: West Yakutat (area between 140 and 147 degrees W. longitude) and East Yakutat/Southeast Outside (area east of 140 degrees W. longitude. Separate ABCs and TACs are now assigned to each of these smaller areas for the pelagic shelf rockfish assemblage.

12.1.3 Evidence of stock structure

No studies have been done to determine if the Gulf of Alaska population of dusky rockfish is one stock, or if subpopulations occur. No stock identification work has been done on dark, widow, or yellowtail rockfish as widow and yellowtail rockfish are generally considered minor species in Alaska waters and dark rockfish have recently been described.

12.1.4 Fishery

Catch History

Fishery catch statistics for the pelagic shelf rockfish complex in the Gulf of Alaska are only available for the years 1988-2005 (Table 12-1a). Specific catches for dusky rockfish were estimated from the Regional Office blend estimates from 1977-2005 for input in the age-structured model (Table 12-1b). Generally, annual catches increased from 1988 to 1992, and have fluctuated in the years following. This pattern is largely explained by management actions that have affected rockfish during this period. In the years before 1991, TAC's were relatively large for more desirable slope rockfish species such as Pacific ocean perch, and there was less reason for fishermen to target a lower valued fish such as dusky rockfish. However, as TAC's for slope rockfish became more restrictive in the early 1990's, there was a greater economic incentive for taking dusky rockfish. As a result, catches of the pelagic shelf assemblage increased, reaching 3,605 mt Gulf-wide in 1992. In following years, in-season management regulations have usually prevented any further increase in the dusky rockfish fishery, and have sometimes caused a decrease in catch. For example, in 1997-1998 and 2000-2005, the pelagic shelf rockfish trawl fishery in the Central area was closed with a substantial amount of un-harvested TAC remaining, either to ensure that catches did not exceed the TAC, or to prevent excessive bycatch of Pacific ocean perch or Pacific halibut.

Catches in Table 12-1a include black and blue rockfish for the years 1988-97, when these species were members of the pelagic shelf assemblage. A significant black rockfish jig fishery started in 1991 in the Gulf of Alaska, but precise catches of black rockfish for these years are not available. Clausen and

Heifetz (1997) provided approximations of the Gulf-wide annual catches of black rockfish for the years 1991-97. The approximation for 1997 was later revised in the 1998 SAFE report (Clausen and Heifetz 1998). These approximations can be subtracted from the Gulf-wide totals in Table 12-1a to yield the following estimates of pelagic shelf rockfish catch for the three species that now comprise the assemblage:

Year	1991	1992	1993	1994	1995	1996	1997
Catch (mt)	1,773	3,163	3,041	2,610	2,342	1,834	2,280

Catches of pelagic shelf rockfish from research cruises since 1977 are listed in Table 12-1c.

Description of the Fishery

Pelagic shelf rockfish (excluding the former members, black and blue rockfish) have been caught almost exclusively with bottom trawls. Species composition data for the present species in the assemblage are shown below for the fishery in the years 1991-2002, based on data from the domestic observer program:

	Percent of assemblage catch			
Year	Dusky	Dark	Yellowtail	Widow
1991	93.5	0.2	5.1	1.2
1992	98.9	0.3	trace	0.8
1993	98.1	trace	0.5	1.4
1994	98.3	1.2	0.1	0.4
1995	99.2	trace	trace	0.8
1996	99.7	trace	trace	0.3
1997	99.9	trace	trace	0.1
1998	99.9	trace	trace	trace
1999	97.4	2.6	trace	trace
2000	99.2	0.6	0.1	0.2
2001	99.7	0.3	trace	trace
2002	99.4	0.5	trace	0.1

Although the vast majority of these catches come from bottom trawls, a small portion of the data may also come from longline vessels that carried observers, which could account for some of the yellowtail and dark rockfish listed. Clearly, with the possible exception of 1991, nearly all the catch consists of dusky rockfish.

The trawl fishery for dusky rockfish in the Gulf of Alaska in recent years has occurred mostly in July, because management regulations do not allow rockfish trawling in the Gulf until the first week in July. The same trawlers that target Pacific ocean perch and northern rockfish also target dusky rockfish. Typically, these vessels fill the quota first for Pacific ocean perch, and after this fishery is closed, move on to catch dusky and northern rockfish. Catches of dusky rockfish are concentrated at a number of relatively shallow, offshore banks of the outer continental shelf, especially the "W" grounds west of Yakutat, Portlock Bank northeast of Kodiak Island, and around Albatross Bank south of Kodiak Island. Highest catch-per-unit-effort in the commercial fishery is generally at depths of 100-149 m (Reuter 1999). During the period 1988-95, almost all the catch of dusky rockfish (>95%) was taken by large factory trawlers that processed the fish at sea. This changed starting in 1996, when smaller shore-based trawlers also began taking a sizeable portion of the catch in the Central Gulf area for delivery to processing plants in Kodiak. These shore-based trawlers have accounted for the following percentages of the trawl catch in the Central area in the years 1996-2004[2]:

1996	1997	1998	1999	2000	2001	2002	2003	2004
27.1	18.1	25.0	45.2	74.4	58.0	49.7	n/a	64.6

Bycatch

Ackley and Heifetz (2001) examined bycatch of Gulf of Alaska rockfish fisheries using data from the observer program for the years 1994-96. For hauls targeting pelagic shelf rockfish, the major bycatch species were northern rockfish and fish in the “other slope rockfish” management category, followed by Pacific ocean perch. Similarly, dusky rockfish was the major bycatch species for hauls targeting northern rockfish. These conclusions are supported by another study (Reuter 1999), in which catch data from the observer program showed dusky rockfish were most commonly associated with northern rockfish, Pacific ocean perch, and harlequin rockfish (the latter is one of the “other slope rockfish” species). There is no information on the bycatch of pelagic shelf rockfish in non-rockfish fisheries, but it is presumed to be small.

Discards

Gulf-wide discard rates (percent of the total catch discarded within management categories) of pelagic shelf rockfish were available for the years 1991-2004. Rates are listed in the following table and have been relatively low over time[3].

Discards (%)	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004
Pelagic Shelf Rockfish	10.2	5.9	10.8	9.4	6.3	10.9	6.4	4.8	9.3	3.8	4.3	4.7	2.4	3.6

In contrast, discard rates in the fisheries for slope rockfish in the Gulf of Alaska have generally been much higher (see chapters for Pacific ocean perch, northern rockfish, rougheye, and other slope rockfish).

12.2 DATA

12.2.1 Data Summary

The following table summarizes the data available for this assessment:

Source	Data	Years
Fisheries	Catch	1977-2005
U.S. trawl fisheries	Length	1990-1999, 2003, 2005
	Age	2000, 2001, 2002, 2004
Domestic trawl survey	Biomass index	1984, 1987, 1990, 1993, 1996, 1999, 2001, 2003, 2005
	Age	1984, 1987, 1990, 1993, 1996, 1999, 2001, 2003

[2]National Marine Fisheries Service, Alaska Region, Fishery Management Section, P.O. Box 21668, Juneau, AK 99802-1688. Data are from weekly production and observer reports through October 14, 2005.

[3]National Marine Fisheries Service, Alaska Region, P.O. 21668, Juneau, AK 99802. Data are from weekly production and observer reports through October 14, 2005.

12.2.2 Fishery Data

Catch

Catch estimates are a combination of foreign observer data, joint venture catch data, and NMFS Regional Office blend data (Table 12-1a, Table 12-1b, Figure 12-1). Catches range from 17 mt in 1986 to 4,538 mt in 1999. We are skeptical of the low catches that occurred prior to 1988 and believe the catches for years 1985-1987 are likely underestimated. Since some of the catch data is of marginal quality prior to 1990, we make adjustments in the dusky model to account for this. These catches occurred during the end of the joint venture years and prior to accurate catch accounting of the newly formed domestic fishery.

Age and Size composition

In addition to the catch data listed in Table 12-1a and 12-1b, length frequency data for dusky rockfish in the commercial fishery are available for the years 1991-2005 (Table 12-2). These data are the raw length frequencies for all dusky rockfish measured by observers. Since there was no attempt to collect or analyze these data systematically, some biases may be expected, especially for 1995 and 1996 when sample sizes were relatively small. Generally, however, these lengths were taken from hauls in which dusky rockfish were either the target or a dominant species, and they provide an indication of the trends in size composition for the fishery. Size of fish taken by the fishery generally appears to have increased after 1992; in particular, the mode increased from 42 cm in 1991-92 to 44-47 cm in 1993-97. The mode then decreased to 42 cm in 1998, and rose back to 45 cm in 1999-2002. Fish smaller than 40 cm are seen in moderate numbers in certain years (1991-92 and 1996-98), but it is unknown if this is an artifact of observer sampling patterns, or if it shows true influxes of younger fish.

Age samples for dusky rockfish have been collected by observers only in the 1999-2005 commercial fisheries. Aging has been completed for the 2000, 2001, 2002 and 2004 samples (Table 12-3). Similar to the fishery length data discussed in the preceding paragraph, the data in Table 12-3 depicts the simple raw age distribution of the samples, and we did not attempt any further analysis to estimate a more comprehensive age composition. However, the samples were randomly collected from fish in over 100 hauls that had large catches of dusky rockfish, so the raw distribution is probably representative of the true age composition of the fishery. The fish ranged in age from 4 to 76 years. Several large and relatively steady year classes are evident through the time series. All four years accurately track the 1987 year class which shows up as 13 year olds in 2000 and the 1992 year class which is evident as eight year olds in 2000. This year class appears especially strong in the 2004 data.

12.2.3 Survey Data

Biomass Estimates from Trawl Surveys

Comprehensive trawl surveys were conducted on a triennial basis in the Gulf of Alaska in 1984, 1987, 1990, 1993, 1996, and 1999, and these surveys became biennial in 2001, 2003, and 2005. The 2001 survey biomass is a weighted average of 1993-1999 biomass estimates, since the Eastern Gulf was not surveyed. The surveys provide estimates of biomass for pelagic shelf rockfish (Table 12-4a). The estimates for the 1984 through 1996 surveys showed that dusky rockfish comprised virtually all the biomass of the assemblage. In 1999, dusky rockfish again predominated, but a relatively large biomass of yellowtail rockfish was also seen in the Southeastern area. This yellowtail rockfish biomass can be mostly attributed to one relatively large catch in Dixon Entrance near the U.S./Canada boundary. In 2005, the dusky and dark rockfish biomass estimates were the highest ever recorded. The dark rockfish biomass was influenced by a large catch of 1154 kg in the Shumagin area. The next largest catch of dark rockfish was 167 kg. Five hauls caught more than 1000 kg of dusky rockfish in the western and central Gulfs which contributed to the high biomass estimate. Dusky rockfish were separated into “light” or “dark” varieties only in the five most recent surveys in 1996, 1999, 2001, 2003, and 2005. Each of these surveys has shown that dusky rockfish (light dusky) overwhelmingly predominate and that dark rockfish (dark dusky) are caught in only small quantities. Presumably, the dusky rockfish biomass in previous surveys also consisted of nearly all dusky rockfish (light dusky). On a geographic basis, the Kodiak statistical area has usually shown the highest biomass of dusky rockfish. Biomass estimates for the assemblage have been consistently lowest in the Southeastern area, with the exception of 1999 when the large catch of yellowtail rockfish was found in this area.

Comparison of Trawl Surveys

Comparative biomass estimates for the nine triennial surveys show wide fluctuations for dusky rockfish (Table 12-4a, Table 12-4b, Figure 12-2). Total estimated biomass increased substantially between 1984 and 1987, dropped by over 50% in 1990, rebounded in 1993 and 1996, and decreased again in 1999 and 2001 (in areas that were sampled in 2001), increased in 2003, and increased 2.5 fold in 2005 to 170,484 mt. Large confidence intervals are associated with all these biomass estimates, particularly in 1987, 1996, 2003, and 2005. This is an indication of the generally patchy and highly aggregated distribution of this species. It is unknown whether these fluctuations indicate true changes in abundance, temporal changes in the availability of dusky rockfish to the survey gear, or are an artifact of the imprecision of the survey for this species. However, because of the apparently light fishing pressure on dusky rockfish during most of these years (catches have usually been much less than the ABC), and their relatively low rate of natural mortality, large and abrupt changes in abundance such as those shown by the trawl surveys seem unlikely. Surveys with the larger biomass estimates do not influence the model as much as lower, more precise estimates because of the high imprecision surrounding the larger biomass estimates.

Survey Size Compositions

Gulf-wide survey size compositions are available from 1984-2005 (Table 12-5). Survey size compositions suggest that recruitment of dusky rockfish is a relatively infrequent event, as only two surveys, 1993 and 2003, showed evidence of substantial recruitment. Mean population length increased from 39.8 cm in 1987 to 43.1 cm in 1990, apparently the result of growth. In 1993, however, a large number of small fish (~27-35 cm long) appeared which formed a sizeable percentage of the population, and this recruitment decreased the mean length to 38.3 cm. In the 1996 and 1999 surveys, the length frequency distribution was similar to that of 1990, with very few small fish, and both years had a mean population length of 43.9 cm. The 2001 size composition, although not directly comparable to previous years because the eastern Gulf of Alaska was not sampled, shows modest recruitment of fish <40 cm. In 2003, a distinct mode of fish is seen at ~30 cm that suggests relatively strong recruitment may be occurring. In 2005, mean population length increased to 42.2 cm and there is no evidence of recruitment of small fish. Survey size compositions are not used in the model because survey ages are used from those same years in the model.

Survey Age Compositions

Gulf-wide age composition data for dusky rockfish are available for the 1984 through 2001 trawl surveys. (Table 12-6), and, similar to the length data, these age data also indicate that recruitment is highly variable. For each survey, ages were determined using the “break-and-burn” method of aging otoliths, and a Gulf-wide age-length key was developed. The key was then used to estimate age composition of the dusky rockfish population in the Gulf of Alaska. The 1976 year class appeared to be abundant in the 1984 survey. This year class is also prominent in the 1987 and 1990 age compositions. In 1987, just 4 year classes (1975, 1976, 1977, and 1980) comprised over 75% of the estimated population, and mean age was 10.5 years. The 1990 results showed no significant recruitment of young fish and appeared to merely reflect growth of the population that existed in 1987; mean age was 14.4 years. The 1993 age composition showed a very prominent 1986 year class. This year class is clearly associated with the large influx of small fish that was noted previously in the 1993 size compositions, and its presence likely explains much of the increase in dusky rockfish biomass that year. The existence of a strong 1986 year class was further confirmed by the 1996 age composition, in which this year class was again the most important. The 1996 results showed little evidence of recruitment of young fish <10 years old; accordingly, mean age of the population increased from 12.1 years in 1993 to 14.7 years in 1996. In 1999, fish <10 years old again comprised only a small part of the population, and fish aged 12, which would correspond to the 1987 year class, were very prominent. Because rockfish are difficult to age, especially as the fish grow older, one possibility is that some of the fish aged 12 in 1999 were actually age 13 (members of the 1986 year class), which would agree more with the 1993 and 1996 age results. The 2001 age compositions show the 1986 year class is still discernable as a distinct mode at age 15. The 2001 data also indicated a possibly strong 1992 year class and that very few fish were >16 year old. Finally, it should be noted that the 2001 fishery age distributions discussed previously in section 12.2.1 agree with these survey age compositions, as they all show prominent 1986 or 1987 year classes.

12.2.4 Age Truncation

According to recent survey age data collected for dusky rockfish, the amount of very old fish (age 24+) has fluctuated since 1984 (24 was chosen as the age that is 40% maximum observed survey age). Naturally, some age-truncation will occur in the presence of fishing. The individual age samples are too small and noisy to compare the sampled age-distributions with what is expected by fishing at F40%. However, we can examine the unweighted average age distribution over time (1984-2003) and compare what we would expect if the population had been fished at $F_{40\%}$ until equilibrium. The expected proportion of age 24+ fish is 0.03, and for most of the surveys the observed proportion seems to be at or above this expected proportion (Figure 12-3). A decrease in older fish could be a result from historic fishing or a high proportion of young fish in the biomass. High proportions of older fish occurred in the 1987, 1993, 1996, and 1999 surveys, while lower than expected proportions were found in the 1984 and 2001 surveys. The 1990 and 2003 surveys were in line with what was expected. Additionally, populations with highly variable recruitment like dusky rockfish can be expected to show fluctuations in age distribution that are unrelated to fishing.

12.2.5 Localized depletion

Localized depletion is defined here as the reduction of population size over a relatively small spatial area as a result of intensive fishing. Localized depletion is a potential conservation issue for rockfish because several species have been observed to be patchily distributed and stock structure could occur at relatively small spatial scales. Thus, intensive fishing upon local spawning populations could potentially lead to significant losses in stock productivity even if the exploitation rate over a broad management area is within management guidelines.

Declines in fishery catch-per-unit-effort (CPUE) within small spatial areas could be indicative of population declines and thus localized depletion. In a recent study prepared for the Lowell-Wakefield Pacific rockfish symposium, several areas were examined for localized depletion in targeted rockfish (Pacific ocean perch, northern rockfish, and dusky rockfish). In this study, 18 blocks, approximately 10,000 km^2, were selected with regular rockfish harvest in the Gulf of Alaska and Aleutian Islands. These areas were further divided in half to make 36 ~5,000 km^2 blocks. Two block sizes were used to try to further understand scale in the detection of localized depletion. Data for the three species were examined from 1991-2004. A Leslie depletion estimator was used to detect population depletion by the fishery via a linear decline in the CPUE as a function of cumulative fish catch since the start of the fishery[4].

Relatively few significant localized depletions were detected for dusky rockfish. One area that localized depletion for dusky rockfish was detected was in 1994 in an area known as the “Snakehead” outside Kodiak Island in the Gulf of Alaska. This area was fished heavily for northern rockfish in the 1990s and showed strong evidence of year-over-year depletion for northern rockfish and some evidence of similar

[4] Hanselman, D.H., P. Spencer, S.K. Shotwell, and R. Reuter. Localized depletion of three Alaskan rockfish species. *In review*. 23rd. Lowell Wakefield Fisheries Symposium on Biology, Assessment, and Management of North Pacific Rockfishes.

depletion for dusky rockfish. Although only one year showed significant depletion in this area using the Leslie estimator, both fishery and survey CPUEs showed continual declines since 1994. This area is now only lightly fished, which may be due to this interannual depletion that occurred in the 1990s. While the study indicated many significant depletions for Pacific ocean perch and a moderate amount for northern rockfish, dusky rockfish showed relatively little evidence of localized depletion. Several reasons for this might include: 1) The local populations may be large enough compared to the existing catch limits that significant depletions do not occur. 2) There is insufficient data for a less targeted species like dusky rockfish to detect real depletions that are happening. 3) The data selection criteria were aimed at the complex of targeted rockfish. If the fishery is starting the fishery concentrating on Pacific ocean perch until the catch limit is reached, then subsequently targeting northern rockfish then dusky rockfish, depletion would be exaggerated for the first target and then underestimated for the final target.

The appropriate spatial and temporal scale at which localized depletion becomes important for rockfish is a subject for future research. Localized depletion becomes problematic if it diminishes the ability of rockfish to replenish fished areas such that local spawning populations are eliminated. Thus, evaluations of localized depletion for rockfish should reflect the spatial scale characterizing fish movement within a year and the location and spatial extent of spawning populations. This information can be obtained from research on early life history and genetic stock structure. From a management perspective, localized aggregations of rockfish are logical candidate areas for spatial management measures. Identification of such areas can be aided if rockfish are observed to associate with certain habitat features.

12.3 ANALYTICAL APPROACH

Due to the lack of biological information for dusky rockfish, assessments prior to 2003 used a biomass-based approach based on trawl survey data to calculate ABC's for pelagic shelf rockfish. We now provide an alternative approach for dusky rockfish that is based on age-structured modeling. However, we still apply the biomass-based approach to compute ABC's for dark, widow, and yellowtail rockfish.

12.3.1 Dark, Widow, and Yellowtail Rockfish

Assessment Parameters
Information on mortality rates and maximum age for three species of pelagic shelf rockfish is shown in Table 12-7. These data are based on the currently accepted "break-and-burn" method of aging otoliths. The method used to determine the natural mortality rate for the pelagic shelf complex was described in Clausen and Heifetz (1991).The estimates range from 0.06-0.09 and were based on dusky rockfish samples. Mortality rates for older rockfish such as Pacific ocean perch and rougheye rockfish are estimated at 0.06 and 0.04, respectively (see specific chapters for these management categories for more information). The value of 0.09 has been used because pelagic shelf rockfish were typically younger than other long-lived rockfish. However, estimates of natural mortality for dark, yellowtail, and widow from different sources using a variety of techniques (e.g. catch curve analysis) indicate that 0.09 may be too high (Table 12-7). We suggest that the value of 0.07 which was recently computed for dark rockfish in the GOA[5] might be more appropriate for dark, widow, and yellowtail, and we recommend this change for the 2005 assessment.

Current Exploitable Biomass
In the last ten SAFE reports (Clausen and Heifetz 1994, 1995, 1996, 1997, 1998, 1999, 2000, and 2001; Clausen et al. 2002, 2003), current exploitable biomass for pelagic shelf rockfish was computed by averaging the Gulf-wide assemblage biomass in the most recent three trawl surveys (i.e., averaging the

[5] Chilton, L. *In Review*. Growth and natural mortality of dark rockfish (Sebastes ciliatus) in the western Gulf of Alaska. 23rd. Lowell Wakefield Fisheries Symposium on Biology, Assessment, and Management of North Pacific Rockfishes.

1987, 1990, and 1993 surveys for the 1994 and 1995 reports, averaging the 1990, 1993, and 1996 surveys for the 1996, 1997, and 1998 reports, etc.). This averaging technique was used because of the uncertainty of the biomass estimates (discussed previously in section 12.2.2, “Comparison of Trawl Surveys”) and the resultant desire to avoid placing too much emphasis on the results of an individual survey.

The Gulf-wide biomass estimates for dark, widow, and yellowtail rockfish for the three most recent surveys in 2001, 2003, and 2005 are 5,003 mt, 1,037 mt, and 25,440 mt respectively (Table 12-4a). Averaging these values yields a current exploitable biomass of 10,493 mt for dark, widow, and yellowtail rockfish. This estimate can be broken down into 8,301 mt for dark rockfish, 168 mt for widow rockfish, and 2,024 mt for yellowtail rockfish.

12.3.2 Dusky Rockfish Model Structure

We present model results for dusky rockfish based on an age-structured model using AD Model Builder software (Otter Research Ltd 2000). In 2003, the stock assessment was first accepted as an alternative to trawl survey biomass estimates. The assessment model is based on a generic rockfish model developed in a workshop held in February 2001[6] and follows closely the GOA Pacific ocean perch and northern rockfish models (Courtney et al 1999; Hanselman et al. 2003). As with other rockfish age-structured models, this model does not attempt to fit a stock-recruitment relationship but estimates a mean recruitment, which is adjusted by estimated recruitment deviations for each year. We do this because there does not appear to be an obvious stock-recruitment relationship in the model estimates, and there is no information on low spawners and low recruits (Figure 12-4). The main difference between the dusky model and the Pacific ocean perch model is that natural mortality is not estimated in the dusky rockfish model. The parameters, population dynamics, and equations of the model are in Box 1.

12.3.3 Parameters Estimated Independently

Life-history parameters including proportion mature at age, and weight at age, were taken from the 2001 Pelagic Shelf Rockfish SAFE Document (Clausen and Heifetz, 2001).

The best length-weight information for dusky rockfish comes from the 1996 triennial survey, in which motion-compensated electronic scales were used to weigh a relatively large sample of individual fish for this species. For combined sexes, using the formula W = aLb, where W is weight in grams and L is fork length in mm, $a = 3.28 \times 10^{-5}$ and b = 2.90 (Martin 1997).

Size at 50% maturity for a relatively small sample (n=64) of female dusky rockfish in the Kodiak area has been estimated to be 42.8 cm fork length (Clausen and Heifetz 1997). Age data for these fish were analyzed using a logistic function, which provided an estimated age at 50% maturity of 11.3 years.

The size-age transition matrix was constructed from the Von Bertalanffy growth curve fit to length and age data collected from triennial trawl surveys from 1984-2003. The transition matrix was constructed by adding normal error with a standard deviation equal to the standard deviation of survey ages for each size class. New estimated parameters are: $L_\infty = 46.6$ cm, $\kappa = 0.23$, and $t_0 = 1.27$.

Aging error matrices were constructed by assuming that the break-and-burn ages were unbiased but had a given amount of normal error around each age. The age error transition matrix was constructed by assuming the same age determination error used for northern rockfish (Courtney et al. 1999).

[6] Rockfish Modeling Workshop, NMFS Auke Bay Laboratory, 11305 Glacier Hwy., Juneau, AK. February, 2001.

New estimates of natural mortality were calculated due to questions about the validity of the high natural mortality rate of dusky rockfish versus other similarly aged rockfish. The method used to determine the natural mortality rate for dusky rockfish was first described in Clausen and Heifetz (1991) and has been used for this assessment in the past. An updated estimate was estimated by Malecha et al. (2004). This estimate was based on the Hoenig (1983) empirical estimator for natural mortality based on maximum lifespan:

$$\frac{-\ln(0.01)}{t_{\max}}$$

This estimate was 0.08 and based on the highest age recorded in the trawl survey of 59. The highest recorded age in the fishery ages was 76, which equates to a Hoenig estimate of 0.06. Additionally, a natural mortality of 0.09 would correspond to a Hoenig maximum age estimate of 51. For this assessment we chose a value of 0.07, which corresponds to recent estimates of M for dark rockfish and is close to estimates for other pelagic rockfish (Table 12-7).

12.3.4 Parameters Estimated Conditionally

Parameters estimated conditionally include but are not limited to: catchability, selectivity (up to full selectivity) for surveys and fishery, recruitment deviations, mean recruitment, fishing mortality, and spawners per recruit levels. Other model parameters are described in Box 1.

12.3.5 Uncertainty

Evaluation of model uncertainty has recently become an integral part of the “precautionary approach” in fisheries management. In complex stock assessment models such as this model, evaluating the level of uncertainty is difficult. One way is to examine the standard errors of parameter estimates from the Maximum Likelihood (ML) approach derived from the Hessian matrix. While these standard errors give some measure of variability of individual parameters, they often underestimate their variance and assume that the joint distribution is multivariate normal. An alternative approach is to examine parameter distributions through Markov Chain Monte Carlo (MCMC) methods (Gelman et al. 1995). When treated this way, our stock assessment is a large Bayesian model, which includes informative (e.g., lognormal natural mortality with a small CV) and noninformative (or nearly so, such as a parameter bounded between 0 and 10) prior distributions. In the models presented in this SAFE report, the number of parameters estimated is 96. In a low-dimensional model, an analytical solution might be possible, but in one with this many parameters, an analytical solution is intractable. Therefore, we use MCMC methods to estimate the Bayesian posterior distribution for these parameters. The basic premise is to use a Markov chain to simulate a random walk through the parameter space which will eventually converge to a stationary distribution which approximates the posterior distribution. Determining whether a particular chain has converged to this stationary distribution can be complicated, but generally if allowed to run long enough, the chain will converge (Jones and Hobert 2001). The “burn-in” is a set of iterations removed at the beginning of the chain. This method is not strictly necessary but we use it as a precautionary measure. In our simulations we removed the first 50,000 iterations out of 5,000,000 and “thinned” the chain to one value out of every thousand, leaving a sample distribution of 4,950. We compared running means of the chain, examined autocorrelation, and examined traces of the chains after removing the “burn-in” and “thinning”. We believe that convergence to the posterior distribution was likely if a long chain was used and obvious problems in diagnostic plots were not encountered. We used these MCMC methods to provide further evaluation of uncertainty in the results below.

BOX 1. AD Model Builder Model Description

Parameter definitions	
y	Year
a	Age classes
l	Length classes
w_a	Vector of estimated weight at age, $a_0 \rightarrow a_+$
m_a	Vector of estimated maturity at age, $a_0 \rightarrow a_+$
a_0	Age at first recruitment
a_+	Age when age classes are pooled
μ_r	Average annual recruitment, log-scale estimation
μ_f	Average fishing mortality
σ_r	Annual recruitment deviation
ϕ_y	Annual fishing mortality deviation
fs_a	Vector of selectivities at age for fishery, $a_0 \rightarrow a_+$
ss_a	Vector of selectivities at age for survey, $a_0 \rightarrow a_+$
M	Natural mortality, fixed
$F_{y,a}$	Fishing mortality for year y and age class a ($fs_a \mu_f e^{\varepsilon}$)
$Z_{y,a}$	Total mortality for year y and age class a ($=F_{y,a}+M$)
$\varepsilon_{y,a}$	Residuals from year to year mortality fluctuations
$T_{a,a'}$	Aging error matrix
$T_{a,l}$	Age to length transition matrix
q	Survey catchability coefficient
SB_y	Spawning biomass in year y, ($=m_a\, w_a\, N_{y,a}$)
q_{prior}	Prior mean for catchability coefficient
$\sigma_{r(prior)}$	Prior mean for recruitment deviations
σ_q^2	Prior CV for catchability coefficient
$\sigma_{\sigma_r}^2$	Prior CV for recruitment deviations

BOX 1 (Continued)

Equations describing the observed data

$\hat{C}_y = \sum_a \frac{N_{y,a} * F_{y,a} * \left(1 - e^{-Z_{y,a}}\right)}{Z_{y,a}} * w_a$	Catch equation
$\hat{I}_y = q * \sum_a N_{y,a} * \frac{s_a}{\max(s_a)} * w_a$	Survey biomass index (mt)
$\hat{P}_{y,a'} = \sum_a \left(\frac{N_{y,a} * s_a}{\sum_a N_{y,a} * s_a} \right) * T_{a,a'}$	Survey age distribution Proportion at age
$\hat{P}_{y,l} = \sum_a \left(\frac{N_{y,a} * s_a}{\sum_a N_{y,a} * s_a} \right) * T_{a,l}$	Survey length distribution Proportion at length
$\hat{P}_{y,a'} = \sum_a \left(\frac{\hat{C}_{y,a}}{\sum_a \hat{C}_{y,a}} \right) * T_{a,a'}$	Fishery age composition Proportion at age
$\hat{P}_{y,l} = \sum_a \left(\frac{\hat{C}_{y,a}}{\sum_a \hat{C}_{y,a}} \right) * T_{a,l}$	Fishery length composition Proportion at length

Equations describing population dynamics

Start year

$$N_a = \begin{cases} e^{\left(\mu_r + \tau_{styr - a_0 - a - 1}\right)}, & a = a_0 \\ e^{\left(\mu_r + \tau_{styr - a_0 - a - 1}\right)} e^{-(a - a_0)M}, & a_0 < a < a_+ \\ \frac{e^{(\mu_r)} e^{-(a-a_0)M}}{\left(1 - e^{-M}\right)}, & a = a_+ \end{cases}$$

Number at age of recruitment

Number at ages between recruitment and pooled age class

Number in pooled age class

Subsequent years

$$N_{y,a} = \begin{cases} e^{\left(\mu_r + \tau_y\right)}, & a = a_0 \\ N_{y-1,a-1} * e^{-Z_{y-1,a-1}}, & a_0 < a < a_+ \\ N_{y-1,a-1} * e^{-Z_{y-1,a-1}} + N_{y-1,a} * e^{-Z_{y-1,a}}, & a = a_+ \end{cases}$$

Number at age of recruitment

Number at ages between recruitment and pooled age classNumber in pooled age class

Formulae for likelihood components

BOX 1 (Continued)

$$L_1 = \lambda_1 \sum_y \left(\ln \left[\frac{C_y + 0.01}{\hat{C}_y + 0.01} \right] \right)^2$$

Catch likelihood

$$L_2 = \lambda_2 \sum_y \frac{\left(I_y - \hat{I}_y\right)^2}{2 * \hat{\sigma}^2 \left(I_y\right)}$$

Survey biomass index likelihood

$$L_3 = \lambda_3 \sum_{styr}^{endyr} -n^*{}_y \sum_a^{a+} \left(P_{y,a} + 0.001\right) * \ln\left(\hat{P}_{y,a} + 0.001\right)$$

Fishery age composition likelihood ($n^*{}_y$ =square root of sample size, with the largest set to one hundred)

$$L_4 = \lambda_4 \sum_{styr}^{endyr} -n^*{}_y \sum_l^{l+} \left(P_{y,l} + 0.001\right) * \ln\left(\hat{P}_{y,l} + 0.001\right)$$

Fishery length composition likelihood

$$L_5 = \lambda_5 \sum_{styr}^{endyr} -n^*{}_y \sum_a^{a+} \left(P_{y,a} + 0.001\right) * \ln\left(\hat{P}_{y,a} + 0.001\right)$$

Survey age composition likelihood

$$L_6 = \lambda_6 \sum_{styr}^{endyr} -n^*{}_y \sum_l^{l+} \left(P_{y,l} + 0.001\right) * \ln\left(\hat{P}_{y,l} + 0.001\right)$$

Survey size composition likelihood

$$L_7 = \frac{1}{2\sigma_q^2} \left(\ln \frac{q}{q_{prior}} \right)^2$$

Penalty on deviation from prior distribution of catchability coefficient

$$L_8 = \frac{1}{2\sigma_{\sigma_r}^2} \left(\ln \frac{\sigma_r}{\sigma_{r(prior)}} \right)^2$$

Penalty on deviation from prior distribution of recruitment deviations

$$L_9 = \lambda_9 \left[\frac{1}{2 * \sigma_r^2} \sum_y \tau_y^2 + n_y * \ln\left(\sigma_r\right) \right]$$

Penalty on recruitment deviations

$$L_{10} = \lambda_{10} \sum_y \phi_y^2$$

Fishing mortality regularity penalty

$$L_{11} = \lambda_{11} \bar{s}^2$$

Average selectivity penalty (attempts to keep average selectivity near 1)

$$L_{12} = \lambda_{12} \sum_{a_0}^{a_+} \left(s_i - s_{i+1}\right)^2$$

Selectivity dome-shapedness penalty – only penalizes when the next age’s selectivity is lower than the previous (penalizes a downward selectivity curve at older ages)

$$L_{13} = \lambda_{13} \sum_{a_0}^{a_+} \left(FD(FD(s_i - s_{i+1})\right)^2$$

Selectivity regularity penalty (penalizes large deviations from adjacent selectivities by adding the square of second differences)

$$L_{total} = \sum_{i=1}^{13} L_i$$

Total objective function value

12.4 Model Evaluation

12.4.1 Alternative Models

We consider two different models in this SAFE, the details of which are described below and in detail in Table 12-9. A large amount of age data is now available for dusky rockfish which allows for some relaxation of restrictions on estimating parameters such as the catchability and the recruitment standard deviation, σ_r. The alternative model (Model 2) considers a variety of changes based on the larger amount of data now available in the model. We recommend the use of Model 2 for determining ABC because it uses a more realistic estimate of natural mortality, has a better fit to available data, and closely follows survey biomass estimates.

12.4.1.1 Model 1: Base model

This model was the author recommended model presented in the 2004 Pelagic Shelf Rockfish assessment (Lunsford et al. 2004) which was accepted to determine the 2005 ABC. In this model there was less weight on the catch data and more weight on the survey biomass data. For this year, we updated this model with the new fishery age and length data, fishery catch and survey biomass.

12.4.1.2 Model 2: Author Recommended

This model builds from Model 1 with a variety of changes to model parameters and available data. We used the updated size-age matrix and removed the fishery size compositions from 1990. This was the first year of the Observer Program and considered experimental in operation. The 1990 length composition showed a large proportion of fish in the lower pooled length bin, which has not been seen in any other length distribution. Therefore, we did not have much confidence in this first year of size compositions. Additionally, because of our lack of confidence in the catch data, we increase the fishing mortality regularity penalty to smooth the predicted catches.

In the rockfish template, the recruitment deviation parameter was originally bounded from (0.001, 2). Sensitivity analyses in the POP model revealed that the upper bound was hit during the convergence, which ended up affecting the final result. The upper bound was increased to 10 in the POP, dusky and rougheye models. Further work on the dusky model revealed that the lower boundary was problematic. At the lower boundary of 0.001, the model, unless constrained with a tight prior, always converged to 0.001, indicating near constant recruitment. This was due to the lognormal structure of the recruitment penalty in the objective function, where very small estimates would cause the penalty to turn negative. Therefore we raised the lower boundary for the estimation of recruitment deviations (σ_r) to 0.3, which was higher than the previous boundary of 0.001. This allowed us to let the model estimate recruitment deviations and catchability with noninformative priors (CV = 100%). Parameter estimates from these noninformative priors were very similar to parameter estimates that used the 2% prior CV on σ_r and the 20% prior CV on q. This suggests that the amount of data now available to the model is informative. An alternative would be to run sensitivity trials using a fixed value of σ_r and choose an appropriate value at which to fix the parameter. Finally, the estimate of mortality was lowered from 0.09 to 0.07, with our line of reasoning from Section 12.3.3.

12.5 Model Results

12.5.1 Model Comparison

Table 12-8 summarizes the results from the two alternative models. Both models have similar data likelihoods. Model 2 does not fit the catch data as well as Model 1, probably a direct result of increasing the weight on the F regularity penalty. However, as mentioned in section 12.2.2, the catch data was estimated from a variety of sources and we do not have much confidence in this information. Model 1 does not fit the fishery sizes as well as Model 2, likely due to the removal of the somewhat anomalous 1990 fishery size composition (Figure 12-5). Model 2 also fits the fishery ages slightly better than Model 1 (Figure 12-6). The 1990 size compositions included an extremely large proportion of younger fish that do not show up in any following year and are also contradictory to the survey size proportions in 1990 (Figure 12-5b, Figure 12-7). The fits to the survey biomasses were similar for both models in the earlier surveys; however, Model 2 tracks the recent increase in survey biomass estimates better than Model 1 (Figure 12-2). Fits to survey age compositions were very similar between the two models (Figure 12-8).

Biomass estimates show varying degrees of linear increase for the two models. Estimates for Model 1 show a fairly steady increase throughout the time series, while estimates for Model 2 begin with a steady increase from 1997-2000 and then increase faster in the more recent years (Figure 12-9, 10). The estimated selectivity curves for the fishery and survey data suggested a pattern similar to what we expected for dusky rockfish (Figure 12-11). The commercial fishery should target larger and subsequently older fish and the survey should sample a larger range of ages. Fishing mortality was fairly consistent between the two models (Figure 12-12). Model 2 has a slightly larger increase in the beginning of the time series and a slightly larger decrease in the most recent years. This is likely due to the increased weight on the fishing mortality regularity penalty. Recruitment is highly variable throughout the time series for both models (Figure 12-13), particularly the most recent years, where typically very little information is known about the population. There also does not seem to be a clear spawner recruit relationship for dusky rockfish as recruitment is apparently unrelated to spawning stock biomass (Figure 12-4).

Results of MCMC simulation show similar confidence bands around the biomass estimates for both models (Figures 12-9, 10). Model 1 is very similar to last year's recommended model (Lunsford et al. 2004), while Model 2 shows tighter confidence bands in the earlier years (1977-2000), and wider bands in the most recent years. MCMC confidence bands for recruitment are fairly small for the earlier years; however the confidence bands nearly contain zero for many years and indicate a source of considerable uncertainty in both models (Figure 12-13).

Goodman et al. (2002) suggested that stock assessment authors use a "management path" graph as a way to evaluate management and assessment performance over time. In a management path we plot estimated fishing mortality relative to the (current) target value and the estimated spawning biomass relative to the (current) target spawning biomass. The management paths from both models suggest that management is on track and has kept the stock in the 'optimum' quadrant where $B_{now}/B_{40\%}$ exceeds one and $F_{now}/F_{40\%}$ continues to stay below one (Figure 12-14). The scenario for both models was very similar and suggested that we fell below $B_{40\%}$ from 1977 through the 1990s.

12.6 Projections and Harvest Alternatives

12.6.1 Amendment 56 Reference Points

Dark, Widow, and Yellowtail

Before the November 2001 SAFE report, widow and yellowtail rockfish were always lumped with dusky (and dark) rockfish in the ABC computations. Exploitable biomass of widow and yellowtail rockfish was multiplied by 0.07 to determine ABC, identical to the procedure used for dusky rockfish. In effect, this meant that all three species were treated as "tier 4" species. According to the 1999 overfishing definitions, however, these species should be assigned to tier 5, because $F_{35\%}$ and $F_{40\%}$ are unknown for these species in Alaska. In tier 5, F_{ABC} is defined to be <=0.75 x M. We now recommend that ABC for these three fish be computed separately from dusky rockfish, and that the tier 5 formula be applied to dark, widow, and yellowtail rockfish. If we assume an M of 0.07 for the three species, F_{ABC} is then 0.75 x M, which equals

0.0525. Multiplying this value of F by the current exploitable biomass for dark, widow, and yellowtail rockfish (10,493 mt; see previous section "exploitable biomass) yields an ABC of 551 mt for 2006. This estimate can be broken down into 436 mt for dark rockfish, 9 mt for widow rockfish, and 106 mt for yellowtail rockfish. This is approximately 80 mt higher than what was recommended in 2003 and 2004. This is mostly because the 2005 survey biomass estimate for dark rockfish was very high and M has been changed to 0.07.

Dusky Rockfish
Amendment 56 to the GOA Groundfish Fishery Management Plan defines the "overfishing level" (OFL), the fishing mortality rate used to set OFL (F_{OFL}), the maximum permissible ABC, and the fishing mortality rate used to set the maximum permissible ABC. The fishing mortality rate used to set ABC (F_{ABC}) may be less than this maximum permissible level, but not greater. Because reliable estimates of reference points related to maximum sustainable yield (MSY) are currently not available but reliable estimates of reference points related to spawning per recruit are available, dusky rockfish in the GOA are managed under Tier 3 of Amendment 56. Tier 3 uses the following reference points: $B_{40\%}$, equal to 40% of the equilibrium spawning biomass that would be obtained in the absence of fishing; $F_{35\%}$,,equal to the fishing mortality rate that reduces the equilibrium level of spawning per recruit to 35% of the level that would be obtained in the absence of fishing; and $F_{40\%}$, equal to the fishing mortality rate that reduces the equilibrium level of spawning per recruit to 40% of the level that would be obtained in the absence of fishing.

Estimation of the $B_{40\%}$ reference point requires an assumption regarding the equilibrium level of recruitment. In this assessment, it is assumed that the equilibrium level of recruitment is equal to the average of age 3 recruits from 1980-2002 (year classes between 1977 and 1999). Other useful biomass reference points which can be calculated using this assumption are $B_{100\%}$ and $B_{35\%}$, defined analogously to $B_{40\%}$. 2005 estimates of these reference points are (in terms of female spawning biomass):

$B_{100\%}$	$B_{40\%}$	$B_{35\%}$	$F_{40\%}$	$F_{35\%}$
45,727	18,291	16,004	0.088	0.108

12.6.2 Specification of OFL and Maximum Permissible ABC

Dark, Widow, and Yellowtail
As described in the above section dark, widow and yellowtail rockfish fall into tier 5 of the overfishing definitions, in which estimates of biomass and natural rate of mortality (M) are the only parameters known. For tier 5 species, F_{OFL} is defined to equal M. This results into a 2006 Gulf-wide OFL of 735 mt. This estimate can be broken down into 581 mt for dark rockfish, 12 mt for widow rockfish, and 142 mt for yellowtail rockfish.

Dusky Rockfish
Female spawning biomass for 2006 is estimated at 24,733 mt. This is above the $B_{40\%}$ value of 18,291 mt. Under Amendment 56, Tier 3, the maximum permissible fishing mortality for ABC is $F_{40\%}$ and fishing mortality for OFL is $F_{35\%}$. Applying these fishing mortality rates for 2006, yields the following ABC and OFL:

$F_{40\%}$	0.088
ABC	4,885
$F_{35\%}$	0.108
OFL	5,927

12.6.3 Projections

To satisfy requirements of the NPFMC's Amendment 56, the National Environmental Policy Act (NEPA), and the Magnuson-Stevens Fishery Conservation and Management Act (MSFCMA), all stock assessments have been asked to provide a set of seven harvest scenarios for future years. For species that are assessed using an age/length-structured model (tiers 1, 2, or 3 in the overfishing definitions), these scenarios can take the form of multi-year projections. For species such as dark, widow, and yellowtail rockfish that are not modeled (tier 4 or higher), such projections are not possible, but yields for just the year 2006 can be computed for scenarios 1-5.

Dark, Widow, and Yellowtail

Scenario 1: In all future years, F is set equal to *max* F_{ABC}. (Rationale: For tier 5 species (dark, widow, yellowtail) F is set equal to max F_{ABC} = 0.75 x M (0.07), and the corresponding yield is 551 mt.)

Scenario 2: In all future years, F is set equal to a constant fraction of *max* F_{ABC}, where this fraction is equal to the ratio of the F_{ABC} value for 2006 recommended in the assessment to the *max* F_{ABC} for 2006. (Rationale: For tier 5 species (dark, widow, yellowtail) F is set equal to the recommended FABC = 0.75 x M (0.07), and the corresponding yield is 551 mt.)

Scenario 3: In all future years, F is set equal to 50% of *max* F_{ABC}. (Rationale: For tier 5 species (dark, widow, yellowtail) F is set equal to 50% of max F_{ABC} = 50% of 0.75 x M (0.07), and the corresponding yield is 276 mt.)

Scenario 4: In all future years, F is set equal to the 2001-2005 average F. (Rationale: For tier 5 species (dark, widow, yellowtail) F is set equal to the average F for 2001-2005. The average F for 2001-2005 is 0.75 x M (0.09), and the corresponding yield is 708 mt.)

Scenario 5: In all future years, F is set equal to zero. (Rationale: F equals 0, and the corresponding yield would be 0.)

Dusky Rockfish

For each scenario, the projections begin with the vector of 2005 numbers at age estimated in the assessment. This vector is then projected forward to the beginning of 2006 using the schedules of natural mortality and selectivity described in the assessment and the best available estimate of total (year-end) catch for 2005. In each subsequent year, the fishing mortality rate is prescribed on the basis of the spawning biomass in that year and the respective harvest scenario. In each year, recruitment is drawn from an inverse Gaussian distribution whose parameters consist of maximum likelihood estimates determined from recruitments estimated in the assessment. Spawning biomass is computed in each year based on the time of peak spawning and the maturity and weight schedules described in the assessment. For the first three years, an estimated catch is used that is equal to the current ratio of catch to TAC. In subsequent years, total catch is assumed to equal the catch associated with the respective harvest scenario in all years. This projection scheme is run 1000 times to obtain distributions of possible future stock sizes, fishing mortality rates, and catches.

Five of the seven standard scenarios will be used in an Environmental Assessment prepared in conjunction with the final SAFE. These five scenarios, which are designed to provide a range of harvest alternatives that are likely to bracket the final TAC for 2006, are as follows ("*max* F_{ABC}" refers to the maximum permissible value of F_{ABC} under Amendment 56):

Scenario 1: In all future years, F is set equal to *max* F_{ABC}. (Rationale: Historically, TAC has been constrained by ABC, so this scenario provides a likely upper limit on future TACs.)

Scenario 2: In all future years, F is set equal to a constant fraction of *max* F_{ABC}, where this fraction is equal to the ratio of the F_{ABC} value for 2006 recommended in the assessment to the *max* F_{ABC} for 2006. (Rationale: When F_{ABC} is set at a value below *max* F_{ABC}, it is often set at the value recommended in the stock assessment.) In this scenario we use pre-specified catch for 2006 to provide a more accurate short-term projection of spawning biomass and ABC for species such as dusky where much of the ABC goes unharvested.

Scenario 3: In all future years, F is set equal to 50% of *max* F_{ABC}. (Rationale: This scenario provides a likely lower bound on F_{ABC} that still allows future harvest rates to be adjusted downward when stocks fall below reference levels.)

Scenario 4: In all future years, F is set equal to the 2001-2005 average F. (Rationale: For some stocks, TAC can be well below ABC, and recent average F may provide a better indicator of F_{TAC} than F_{ABC}.)

Scenario 5: In all future years, F is set equal to zero. (Rationale: In extreme cases, TAC may be set at a level close to zero.)

Two other scenarios are needed to satisfy the MSFCMA's requirement to determine whether a stock is currently in an overfished condition or is approaching an overfished condition. These two scenarios are as follows (for Tier 3 stocks, the MSY level is defined as *B35%*):

Scenario 6: In all future years, F is set equal to F_{OFL}. (Rationale: This scenario determines whether a stock is overfished. If the stock is expected to be 1) above its MSY level in 2006 or 2) above ½ of its MSY level in 2006 and above its MSY level in 2016 under this scenario, then the stock is not overfished.)

Scenario 7: In 2006 and 2007, F is set equal to *max* F_{ABC}, and in all subsequent years, F is set equal to F_{OFL}. (Rationale: This scenario determines whether a stock is approaching an overfished condition. If the stock is expected to be above its MSY level in 2018 under this scenario, then the stock is not approaching an overfished condition.)

12.6.4 Status Determination (Dusky Rockfish only)

Harvest scenarios #6 and #7 are intended to permit determination of the status of a stock with respect to its minimum stock size threshold (MSST). Any stock that is below its MSST is defined to be *overfished*. Any stock that is expected to fall below its MSST in the next two years is defined to be *approaching* an overfished condition. Harvest scenarios #6 and #7 are used in these determinations as follows:

Is the stock overfished? This depends on the stock's estimated spawning biomass in 2006:

a) If spawning biomass for 2006 is estimated to be below ½ $B_{35\%}$, the stock is below its MSST.
b) If spawning biomass for 2006 is estimated to be above $B_{35\%}$, the stock is above its MSST.
c) If spawning biomass for 2006 is estimated to be above ½ $B_{35\%}$ but below $B_{35\%}$, the stock's status relative to MSST is determined by referring to harvest scenario #6 (Table 12-9). If the mean spawning biomass for 2016 is below $B_{35\%}$, the stock is below its MSST. Otherwise, the stock is above its MSST.

Is the stock approaching an overfished condition? This is determined by referring to harvest scenario #7 (Table 12-9):

a) If the mean spawning biomass for 2006 is below ½ $B_{35\%}$, the stock is approaching an overfished condition.
b) If the mean spawning biomass for 2006 is above $B_{35\%}$, the stock is not approaching an

overfished condition.
c) If the mean spawning biomass for 2006 is above ½ $B_{35\%}$ but below $B_{35\%}$, the determination depends on the mean spawning biomass for 2018. If the mean spawning biomass for 2018 is below $B_{35\%}$, the stock is approaching an overfished condition. Otherwise, the stock is not approaching an overfished condition.

A summary of the results of these scenarios for dusky rockfish is in Table 12-9. For dusky rockfish the stock is not overfished and is not approaching an overfished condition.

12.6.5 Area Allocation of Harvests

In all previous years, annual allocation of the Gulf-wide ABC for pelagic shelf rockfish amongst the three regulatory areas in the Gulf has been based on the geographic distribution of pelagic shelf rockfish biomass in the trawl surveys. Since the 1996 SAFE report, this distribution has been computed as a weighted average of the percent biomass distribution for each area in the three most recent trawl surveys. In the computations, each successive survey is given a progressively heavier weighting using factors of 4, 6, and 9, respectively. This 4:6:9 weighting scheme was originally recommended by the Gulf of Alaska Groundfish Plan Team, and had already been used for Pacific ocean perch in the 1996 fishery. The Plan Team believed that for consistency among the rockfish assessments, the same weighting should be applied to pelagic shelf rockfish. The Plan Team's scheme was adopted for the 1997 fishery, and we have continued to follow it. Therefore, based on a 4:6:9 weighting of the 2001, 2003, and 2005 trawl surveys, the percent distribution of pelagic shelf rockfish biomass in the Gulf of Alaska is: Western area, 26%; Central area, 60%, and Eastern area, 14%. Applying these percentages to the ABC of dark, widow, and yellowtail (551 mt) yields the following apportionments for the Gulf in 2006: Western area, 146 mt; Central area, 331 mt; and Eastern area, 75 mt. Applying these percentages to the ABC of dusky rockfish (4,885 mt) yields the following apportionments for the Gulf in 2006: Western area, 1,292 mt; Central area, 2,931 mt; and Eastern area, 662 mt (Table 12-10). The total ABC apportionments for the pelagic shelf rockfish complex in 2006 are: Western area, 1,438 mt; Central area, 3,262 mt; and Eastern area, 736 mt.

Because the Eastern area is now divided into two management areas for pelagic shelf rockfish, i.e., the West Yakutat area (area between 147 degrees W. longitude and 140 degrees W. longitude) and the East Yakutat/Southeast Outside area (area east of 140 degrees W. longitude), the ABC for this management group in the Eastern area must be further apportioned between these two smaller areas. The weighted average method described above results in a point estimate of 0.2214 for the proportion of biomass in the Eastern area that occurs in West Yakutat. In this case the average was based on the 1999, 2003, and 2005 surveys because the 2001 survey did not sample the eastern Gulf of Alaska. This translates into an ABC for the pelagic shelf rockfish complex of 163 mt (17 mt for other pelagics and 146 mt for dusky rockfish) for West Yakutat and 573 mt (58 mt for other pelagics and 515 mt for dusky rockfish) for East Yakutat/Southeast Outside in 2006. However, there is considerable uncertainty in the point estimate. In an effort to balance this uncertainty with associated costs to the fishing industry, the Gulf of Alaska Plan Team has recommended that apportionment to the two smaller areas in the eastern Gulf be based on the upper 95% confidence limit of the weighted average of the estimates of the eastern Gulf biomass proportion that is in the West Yakutat area. The upper 95% confidence interval of this proportion is 0.4084, so that the pelagic shelf rockfish complex ABC for West Yakutat would be 301 mt (30 mt for other pelagics and 270 mt for dusky rockfish), and the ABC for East Yakutat/Southeast Outside would be 436 mt (44 mt for other pelagics and 391 mt for dusky rockfish, Table 12-10).

One possible problem was mentioned in 2003 concerning the above apportionment scheme to determine the ABC in the West Yakutat and East Yakutat/Southeast Outside areas. Two recent trawl surveys of the eastern Gulf of Alaska in 1999 and 2003 found very low biomass estimates of pelagic shelf rockfish in the West Yakutat area. In these surveys, the biomass in West Yakutat only comprised 2.6% and 11.1%, respectively, of the total assemblage biomass in the eastern Gulf. In contrast, the 1990, 1993, and 1996 surveys showed the percentages in West Yakutat were 67.5, 43.8, and 61.3, respectively. In 2005, West Yakutat comprised 61.0% of the total assemblage biomass. The 1999 and 2003 estimates are likely due to sampling issues and do not reflect an actual downward shift in the proportion of biomass in West Yakutat. Therefore, we continue to use the current weighting scheme and the upper 95% confidence interval to determine this area's allocation.

12.6.6 Overfishing Definition

Based on the definitions for overfishing in Amendment 44 in tier 3a (i.e., FOFL = F35%=0.108), overfishing is set equal to 5,982 mt for dusky rockfish. For tier 5 species, F_{OFL} is defined to equal M, and F_{ABC} is <= 0.75 x M. This equates into a 2006 Gulfwide OFL of 735 mt for dark, widow, and yellowtail rockfish. The combined 2006 OFL for pelagic shelf rockfish is 6,717 mt (Table 12-10).

12.7 Other Considerations

12.7.1 Management Problems Involving Dark Rockfish

Although black and blue rockfish have been removed from the pelagic shelf assemblage, one management problem that remains is the taxonomic distinction between dusky rockfish and dark rockfish. We note that the two forms of dusky rockfish commonly recognized as "light dusky rockfish" and "dark dusky rockfish" are now officially recognized as two species (Orr and Blackburn 2004). *Sebastes ciliatus* applies to the dark shallow-water species with a common name dark rockfish, and *S. variabilis* applies to variably colored deeper-water species with a common name dusky rockfish. The inshore habitat of dark rockfish is one that this variety shares with black and blue rockfish. This suggests that from a biological perspective, it may be more logical for dark rockfish to be grouped with the latter two species, rather than in the pelagic shelf assemblage. Moreover, information from ADF&G indicates that in past years a sizeable portion (perhaps 25%) of the fish reported as "black rockfish" in the Kenai Peninsula jig fishery may have actually been dark dusky rockfish.[7] Dark rockfish and black rockfish often co-occur in nearshore kelp beds of the Gulf of Alaska, and they are superficially similar in appearance, especially in body color, which leads to misidentification.

In 2003 we recommended removing dark rockfish from the pelagic shelf assemblage and transferring it to state jurisdiction when it was determined to be a valid species. This recommendation is similar to what has been done for black and blue rockfish. Since official recognition as a separate species, the GOA Plan Team has also endorsed removing dark rockfish from the FMP based on the following rationale: (1) separation at species level, (2) distribution of dark rockfish to nearshore habitats that are not specifically assessed by the GOA trawl survey, and (3) the risk of overfishing dark rockfish in local areas given the relatively high TAC for the pelagic shelf rockfish assemblage as a whole. In 2004, the SSC endorsed the rationale and agreed with the Plan Team's recommendation of removing dark rockfish from the FMP. The Council initiated this in 2005 but action has been delayed until the 2005 GOA trawl survey data becomes available for analysis.

12.8 Ecosystem Considerations

In general, a determination of ecosystem considerations for pelagic shelf rockfish is hampered by the lack of biological and habitat information for dusky rockfish. A summary of the ecosystem considerations presented in this section is listed in Table 12-11. Additionally, we include a summary of nontarget species

[7]W. Bechtol, Alaska Department of Fish and Game, 3298 Douglas St., Homer, AK 99603. Pers. commun. August 1995.

bycatch estimates and proportion of total catch for Gulf of Alaska rockfish targeted fisheries 2003-2005 (Table 12-12).

12.8.1 Ecosystem Effects on the Stock

Prey availability/abundance trends: similar to many other rockfish species, stock condition of dusky rockfish appears to be greatly influenced by periodic abundant year classes. Availability of suitable zooplankton prey items in sufficient quantity for larval or post-larval dusky rockfish may be an important determining factor of year class strength. Unfortunately, there is no information on the food habits of larval or post-larval rockfish to help determine possible relationships between prey availability and year class strength; moreover, field-collected larval dusky rockfish at present cannot even be visually identified to species. Adult dusky rockfish consume mostly euphausiids (Yang 1990). Euphausiids are also a major item in the diet of walleye pollock, Pacific ocean perch, and northern rockfish. Changes in the abundance of these three species could lead to a corollary change in the availability of euphausiids, which would then have an impact on dusky rockfish.

Predator population trends: there is no documentation of predation on dusky rockfish. Larger fish such as Pacific halibut that are known to prey on other rockfish may also prey on adult dusky rockfish, but such predation probably does not have a substantial impact on stock condition. Predator effects would likely be more important on larval, post-larval, and small juvenile dusky rockfish, but information on these life stages and their predators is nil.

Changes in physical environment: strong year classes corresponding to the period 1976-77 have been reported for many species of groundfish in the Gulf of Alaska, including walleye pollock, Pacific ocean perch, northern rockfish, sablefish, and Pacific cod. As discussed in Section 12.2.2, age data for dusky rockfish indicates that the 1976 and/or 1977 year classes were also usually strong for this species. Therefore, it appears that environmental conditions may have changed during this period in such a way that survival of young-of-the-year fish increased for many groundfish species, including dusky rockfish. The environmental mechanism for this increased survival of dusky rockfish, however, remains unknown. Pacific ocean perch and dusky rockfish both appeared to have strong 1986 year classes, and this may be another year when environmental conditions were especially favorable for rockfish species.

12.8.2 Fishery Effects on the Ecosystem

Fishery-specific contribution to bycatch of HAPC biota: there is limited habitat information on adult dusky rockfish, especially regarding the habitat of the major fishing grounds for this species in the Gulf of Alaska. Nearly all the catch of dusky rockfish, however, is taken by bottom trawls, so the fishery potentially could affect HAPC biota such as corals or sponges if it occurred in localities inhabited by those biota. Corals and sponges are usually found on hard, rocky substrates, and there is some evidence that dusky rockfish may be found in such habitats. On submersible dives on the outer continental shelf of the eastern Gulf of Alaska, light dusky rockfish were observed in association with rocky habitats and in areas with extensive sponge beds, where the fish were observed resting in large vase-type sponges.[8] Also, dusky rockfish often co-occur and are caught with northern rockfish in the commercial fishery and in trawl surveys (Reuter 1999), and there is information to suggest that northern rockfish are associated with a rocky or rough bottom habitat (Clausen and Heifetz 2002). Based on this indirect evidence, it can be surmised that dusky rockfish are likely also associated with a rocky substrate. An analysis of bycatch of HAPC biota in commercial fisheries in the Gulf of Alaska in 1997-99 indicated that the dusky rockfish trawl fishery ranked fourth (after the deepwater flatfish, walleye pollock, and Pacific ocean perch bottom trawl fisheries) among all fisheries in the amount of corals taken as bycatch and sixth in the amount of

[8] V.M. O'Connell, Alaska Dept. of Fish and Game, 304 Lake St., Sitka, AK 99835. Pers. commun. July 1997.

sponges taken (National Marine Fisheries Service 2001). Little is known, however, about the extent of these HAPC biota and whether the bycatch is detrimental.

Fishery-specific concentration of target catch in space and time relative to predator needs in space and time (if known) and relative to spawning components: the dusky rockfish trawl fishery in the Gulf of Alaska starts in July and usually lasts only a few weeks. As mentioned previously in section 10.2.2, the fishery is concentrated at a number of offshore banks on the outer continental shelf. There is no published information on time of year of insemination or parturition (larval release), but insemination is likely in the fall or winter, and anecdotal observations indicate parturition is mostly in the spring. Hence, reproductive activities are probably not directly affected by the commercial fishery.

Fishery-specific effects on amount of large size target fish: a comparison between Figure 12-5 (length frequency in the commercial fishery) and Figure 12-7 (size composition in the trawl surveys) suggests that although the fishery does not catch many small fish <40 cm length, neither does it particularly target on very large fish.

Fishery contribution to discards and offal production: fishery discard rates of pelagic shelf rockfish have been quite low in recent years, as they have averaged only about 6% in the period 1997-2002. The discard amount of species other than pelagic shelf rockfish in the dusky rockfish fishery is unknown.

Fishery-specific effects on age-at-maturity and fecundity of the target fishery: unknown, but based on the size of 50% maturity of female dusky rockfish reported in this document (42.8 cm), the fishery length frequency distributions in Figure 10-1 suggest that in some years the fishery may be catching a sizeable number of immature fish.

Fishery-specific effects on EFH non-living substrate: unknown, but the heavy-duty “rockhopper” trawl gear commonly used in the fishery can move around rocks and boulders on the bottom.

12.8.3 Data Gaps and Research Priorities

There is no information on larval, post-larval, or early stage juvenile dusky rockfish. Larval dusky rockfish cannot even be identified in plankton samples except by using genetic techniques, which are very high in cost and manpower. Habitat requirements for larval, post-larval, and early stage juvenile dusky rockfish are completely unknown. Habitat requirements for later stage juvenile and adult fish are anecdotal or conjectural. Research needs to be done on the bottom habitat of the major fishing grounds, on what HAPC biota are found on these grounds, and on what impact bottom trawling has on these biota.

12.9 Summary

A summary of biomass levels, exploitation rates and recommended ABC and OFLs for the pelagic shelf rockfish complex is in the following table:

	2005	**2006**	2007*
Dark, Widow, and Yellowtail	2004 Estimates[9]	**This year's estimates**	
Tier 5			
Exploitable Biomass	7,036	**10,493**	-
M	0.09	**0.07**	0.07
F_{ABC} (maximum allowable = *0.75**M)	0.0675	**0.0525**	0.0525
F_{OFL} (M)	0.09	**0.07**	0.07
ABC (mt, maximum allowable)	497	**551**	551
OFL (mt)	663	**735**	735
	2004 Model Projection[10]	This year's projection	
Dusky Rockfish	Not Updated	Revised Model	
Tier 3a			
Total Biomass (4+)	58,519	**86,893**	-
Exploitable Biomass	38,942	**49,829**	-
B_{2006} (mt, female spawning)	17,126	**24,733**	26,502
$B_{100\%}$ (mt, female spawning)	35,749	**45,727**	-
$B_{40\%}$ (mt, female spawning)	14,300	**18,291**	18,291
$B_{35\%}$ (mt, female spawning)	12,512	16,004	-
M	0.09	0.07	0.07
$F_{50\%}$	0.080	0.060	0.060
F_{ABC} (maximum allowable = $F_{40\%}$)	0.120	**0.088**	0.088
F_{OFL} ($F_{35\%}$)	0.148	**0.108**	0.108
$ABC_{F50\%}$	2,719	3,320	3,384
$ABC_{F40\%}$ (mt, maximum allowable)	4,056	**4,885**	4,979
OFL (mt, $F_{35\%}$)	5,018	**5,927**	6,044
Pelagic Shelf Rockfish Complex	2004 Estimates	**This year's estimates**	
Exploitable Biomass	45,978	**60,322**	-
M	0.09	**0.07**	-
$ABC_{F40\%}$ (mt, maximum allowable)	4,553	**5,436**	5,530
OFL (mt, $F_{35\%}$)	5,681	**6,662**	6,779

*The 2007 ABC and OFL for dusky rockfish were projected using an expected catch value of 2,649 mt for 2006. This estimate is based on recent ratios of catch to maximum permissible ABC. The Author's F method was used for this projection (Table 12-9) in response to management requests for a more accurate one-year projection. These values were added to the projected 2007 ABC and OFL for other pelagic rockfish (rolled over from 2006) to derive the 2007 pelagic shelf rockfish ABC and OFL.

[9] 2004 Gulf of Alaska shortraker/rougheye and other slope rockfish, SAFE, Executive Summary
[10] 2004 Gulf of Alaska shortraker/rougheye and other slope rockfish, SAFE, Appendix B model output

Continued work will be done to improve and refine the dusky age-structured model. Dusky rockfish now have more data available for an age-structured assessment, which should allow for some relaxation of previous restrictions on model parameters. We hope that we will be able to obtain larger sample sizes of age data in the future. This will allow us to develop an age error transition matrix applicable to dusky rockfish rather than assuming the same age determination error found for northern rockfish. The current sample sizes are too small to be precise for any ages away from the center of the distribution. Improving the data may allow the model to estimate parameters such as natural mortality and recruitment more effectively. MCMC simulations will continue to be used to explore parameter interactions and the distributions of key parameters.

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Table 12-1a. Commercial catch[a] (mt) of fish in the pelagic shelf rockfish assemblage in the Gulf of Alaska, with Gulfwide values of acceptable biological catch (ABC) and total allowable catch (TAC), 1988-2005. Updated through October 18, 2005.

Year	Category	Regulatory Area[b]					Gulfwide	Gulfwide	Gulfwide
		Western	Central	Eastern	West Yakutat[c]	Southeast Outside[d]	Total	ABC	TAC
1988	Foreign	0	0	0	-	-	0		
	U.S.	400	517	168	-	-	1,085		
	JV	Tr	1	0	-	-	1		
	Total	400	518	168	-	-	1,086	3,300	3,300
1989	U.S.	113	888	737	-	-	1,738	6,600	3,300
1990	U.S.	165	955	527	-	-	1,647	8,200	8,200
1991	U.S.	215	1,191	936	-	-	2,342	4,800	4,800
1992	U.S.	105	2,622	887	-	-	3,605	6,886	6,886
1993	U.S.	238	2,061	894	-	-	3,193	6,740	6,740
1994	U.S.	290	1,702	997	-	-	2,989	6,890	6,890
1995	U.S.	108	2,247	536	471	64	2,891	5,190	5,190
1996	U.S.	182	1,849	265	190	75	2,296	5,190	5,190
1997	U.S.	96	1,959	574	536	38	2,629	5,140	5,140
1998	U.S.	60	2,477	576	553	22	3,113	4,880	4,880
1999	U.S.	130	3,835	694	672	22	4,659	4,880	4,880
2000	U.S.	190	3,074	467	445	22	3,731	5,980	5,980
2001	U.S.	121	2,436	451	439	12	3,008	5,980	5,980
2002	U.S.	185	2,680	457	448	9	3,322	5,490	5,490
2003	U.S.	219	2,209	620	607	13	3,048	5,490	5,490
2004	U.S.	281	2,182	211	199	12	2,885	4,470	4,470
2005	U.S.	118	1,843	218	215	3	2,397	4,553	4,553

[a]Catches for 1988-97 include black rockfish and blue rockfish, which were members of the assemblage during those years.
[b]Catches for West Yakutat and Southeast Outside areas are not available for years before 1996. Eastern area is comprised of the West Yakutat and Southeast Outside areas combined.
[c]West Yakutat area is comprised of statistical areas 640 and 649.
[d]Southeast Outside area is comprised of statistical areas 650 and 659.

Notes: There were no foreign or joint venture catches after 1988. Catches in 1988 are landed catches only. Catches in 1989-91 also include fish reported in weekly production reports as discarded by fishermen or processors. Catches in 1992-2005 also include discarded fish, as determined through a "blend" of weekly production reports and information from the domestic observer program. Definition of terms: JV = joint venture production; U.S. = domestic annual production; Tr = trace catches.

Table 12-1b. Estimated catch (mt) history for dusky rockfish. Values from 1977-2005 are a combination of foreign observer data, joint venture catch data, and NMFS Regional Office blend data. Values are used in age-structured model for dusky rockfish.

Year	Catch
1977	388
1978	162
1979	224
1980	597
1981	845
1982	852
1983	1017
1984	540
1985	34
1986	17
1987	19
1988	1067
1989	1707
1990	1612
1991	2190
1992	3565
1993	3132
1994	2938
1995	2868
1996	2289
1997	2626
1998	3110
1999	4538
2000	3701
2001	3007
2002	3298
2003	3042
2004	2651
2005	2179

Table 12-1c. Catch (mt) of pelagic shelf rockfish taken during research cruises in the Gulf of Alaska, 1977-2005. (Catches before 2002 do not include longline surveys; tr=trace)

Year	Catch
1977	0.4
1978	0.5
1979	0.9
1980	0.2
1981	7.4
1982	1.0
1983	0.5
1984	6.5
1985	6.8
1986	0.3
1987	34.4
1988	0.0
1989	0.1
1990	4.8
1991	0.0
1992	tr
1993	6.8
1994	0.0
1995	0.0
1996	7.4
1997	0.0
1998	2.5
1999	6.7
2000	0.0
2001	2.7
2002	tr
2003	5.9
2004	tr
2005	13.7

Table 12-2. Fishery size compositions and sample size by year for dusky rockfish in the Gulf of Alaska. Lengths below 21 are pooled and lengths greater than 47 are pooled.

	Year												
Length (cm)	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2003	2004	2005
21	0.247	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.001	0.000	0.247
22	0.027	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.027
23	0.008	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.008
24	0.021	0.000	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.021
25	0.036	0.000	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.036
26	0.021	0.000	0.002	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.021
27	0.016	0.000	0.002	0.000	0.000	0.000	0.003	0.000	0.000	0.000	0.000	0.000	0.016
28	0.030	0.000	0.002	0.000	0.002	0.000	0.003	0.000	0.000	0.000	0.001	0.000	0.030
29	0.021	0.001	0.003	0.000	0.001	0.000	0.011	0.000	0.000	0.000	0.000	0.000	0.021
30	0.029	0.003	0.005	0.000	0.002	0.000	0.017	0.000	0.000	0.000	0.000	0.000	0.029
31	0.017	0.003	0.012	0.000	0.001	0.000	0.008	0.001	0.000	0.000	0.000	0.000	0.017
32	0.025	0.003	0.013	0.000	0.000	0.000	0.006	0.002	0.000	0.000	0.000	0.001	0.025
33	0.013	0.005	0.016	0.000	0.002	0.000	0.019	0.004	0.000	0.000	0.000	0.001	0.013
34	0.017	0.008	0.019	0.000	0.001	0.000	0.011	0.009	0.000	0.000	0.001	0.001	0.017
35	0.009	0.025	0.019	0.000	0.004	0.003	0.006	0.021	0.000	0.002	0.003	0.003	0.009
36	0.006	0.029	0.015	0.000	0.004	0.005	0.014	0.028	0.000	0.002	0.006	0.005	0.006
37	0.013	0.019	0.016	0.001	0.003	0.004	0.011	0.045	0.001	0.001	0.008	0.004	0.013
38	0.006	0.024	0.027	0.001	0.009	0.003	0.003	0.044	0.005	0.004	0.013	0.014	0.006
39	0.002	0.069	0.037	0.006	0.004	0.012	0.008	0.036	0.009	0.006	0.020	0.022	0.002
40	0.016	0.084	0.111	0.020	0.019	0.016	0.033	0.040	0.023	0.011	0.029	0.036	0.016
41	0.020	0.134	0.121	0.046	0.041	0.029	0.053	0.065	0.051	0.028	0.052	0.052	0.020
42	0.065	0.145	0.127	0.103	0.074	0.046	0.069	0.096	0.104	0.079	0.088	0.088	0.065
43	0.084	0.140	0.115	0.145	0.076	0.077	0.092	0.117	0.146	0.115	0.112	0.106	0.084
44	0.091	0.136	0.115	0.200	0.146	0.087	0.108	0.123	0.175	0.164	0.145	0.147	0.091
45	0.138	0.086	0.099	0.197	0.171	0.124	0.128	0.130	0.167	0.181	0.139	0.149	0.138
46	0.008	0.057	0.071	0.151	0.176	0.136	0.136	0.103	0.125	0.149	0.135	0.137	0.008
47	0.014	0.034	0.050	0.131	0.266	0.459	0.261	0.137	0.192	0.258	0.247	0.233	0.014
Sample size	187	582	1141	653	595	312	120	637	597	933	2046	1235	1517

Table 12-3. Fishery age compositions for dusky rockfish in the Gulf of Alaska. Ages are binned below 4 and 21 years and greater.

Age(yr)	2000	2001	2002	2004
4	0.000	0.000	0.000	0.000
5	0.000	0.000	0.000	0.000
6	0.002	0.002	0.000	0.000
7	0.000	0.004	0.007	0.007
8	0.012	0.004	0.009	0.009
9	0.007	0.043	0.011	0.011
10	0.036	0.035	0.104	0.104
11	0.048	0.068	0.109	0.109
12	0.143	0.077	0.095	0.095
13	0.206	0.132	0.064	0.064
14	0.211	0.170	0.154	0.154
15	0.099	0.161	0.134	0.134
16	0.051	0.089	0.120	0.120
17	0.027	0.060	0.052	0.052
18	0.015	0.031	0.025	0.025
19	0.015	0.012	0.011	0.011
20	0.012	0.017	0.007	0.007
21+	0.116	0.097	0.098	0.098
Sample size	413	517	441	452

Table 12-4a. Biomass estimates (mt) for species in the pelagic shelf rockfish assemblage in the Gulf of Alaska, based on results of bottom trawl surveys from 1984 through 2005.

	Statistical Area					
Species	Shumagin	Chirikof	Kodiak	Yakutat	South-eastern	Total
		1984				
Dusky rockfish	3,843	7,462	4,329	15,126	307	31,068
Yellowtail rockfish	0	0	0	17	454	471
Total, all species	3,843	7,462	4,329	15,143	761	31,539
		1987				
Dusky rockfish	12,011	4,036	46,005	18,346	1,097	81,494
Widow rockfish	0	0	0	51	96	147
Total, all species	12,011	4,036	46,005	18,397	1,193	81,641
		1990				
Dusky rockfish	2,963	1,233	16,779	5,808	953	27,735
Widow rockfish	0	0	0	285	0	285
Total, all species	2,963	1,233	16,779	6,093	953	28,020
		1993				
Dusky rockfish	11,450	12,880	23,780	7,481	1,626	57,217
Total, all species	11,450	12,880	23,780	7,481	1,626	57,217
		1996				
Light dusky rockfish	3,553	19,217	36,037	14,193	1,480	74,480
Dark dusky rockfish	152	139	59	0	0	350
Widow rockfish	0	10	0	0	919	929
Yellowtail rockfish	0	0	20	0	65	85
Total, all species	3,704	19,366	36,116	14,193	2,464	75,843
		1999				
Light dusky rockfish	2,538	9,157	33,729	2,097	2,108	49,628
Dark dusky rockfish	2,130	31	49	0	0	2,211
Widow rockfish	0	0	69	0	115	184
Yellowtail rockfish	0	0	0	162	12,509	12,671
Total, all species	4,668	9,188	33,847	2,259	14,732	64,694

(Table continued on next page.)

Table 12-4a (continued). Biomass estimates (mt) for species in the pelagic shelf rockfish assemblage in the Gulf of Alaska, based on results of bottom trawl surveys from 1984 through 2005.

	Statistical Area					
Species	Shumagin	Chirikof	Kodiak	Yakutat	South-eastern	Total
		2001				
Light dusky rockfish	5,352	2,062	23,590	7,924[a]	1,738[a]	40,667[a]
Dark dusky rockfish	362	15	36	0[a]	0[a]	413[a]
Widow rockfish	0	0	0	0[a]	345[a]	345[a]
Yellowtail rockfish	0	0	0	54[a]	4,192[a]	4,245[a]
Total, all species	5,714	2,077	23,626	7,978[a]	6,275[a]	45,670[a]
		2003				
Light dusky rockfish	4,039	46,729	7,198	11,519	1,377	70,862
Dark dusky rockfish	235	49	16	0	0	300
Widow rockfish	0	0	0	0	32	32
Yellowtail rockfish	0	0	0	71	635	705
Total, all species	4,274	46,778	7,214	11,590	2,044	71,899
		2005				
Dusky rockfish	69,295	38,216	60,097	2,488	389	170,484
Dark rockfish	21,454	389	2,348	0	0	24,191
Widow rockfish	0	0	51	0	77	128
Yellowtail rockfish	0	0	0	0	1,121	1,121
Total, all species	90,749	38,605	62,445	2,448	1,587	195,924

[a]Note: The Yakutat and Southeastern areas were not sampled in the 2001 survey. Estimates of biomass for these two areas in 2001 were obtained by averaging the corresponding area biomasses in the 1993, 1996, and 1999 surveys.

Table 12-4b. GOA dusky rockfish biomass estimates and standard errors from NMFS triennial/biennial trawl surveys in the Gulf of Alaska.

Year	1984	1987	1990	1993	1996	1999	2001	2003	2005
Biomass	31,068	94,212	26,827	57,217	74,480	49,540	41,905	70,862	170,484
S.E.	7,146	29,391	8,635	16,590	32,851	19,193	11,634	34,352	51,657
LCI	16,776	35,430	9,557	24,037	8,778	11,154	18,637	2,158	68,202
UCI	45,360	152,994	44,097	90,397	140,182	87,926	65,173	139,566	272,766

Table 12-5. NMFS trawl survey length compositions for dusky rockfish in the Gulf of Alaska. Fish 21 cm and less are pooled into length 21 and fish 47cm and greater are pooled. Survey size compositions are not used in model.

Length (cm)	1984	1987	1990	1993	1996	1999	2001	2003	2005
21	0	0.002	0	0.005	0.003	0.001	0.007	0.001	0.004
22	0	0.001	0.008	0.002	0.002	0.001	0.002	0.004	0.001
23	0	0.001	0.004	0.004	0.004	0.001	0.003	0	0.001
24	0	0	0.002	0.007	0.003	0	0.005	0.001	0.002
25	0	0	0.006	0.002	0.003	0.002	0.003	0	0.002
26	0	0.001	0	0.015	0.001	0	0.004	0.004	0.001
27	0	0	0.007	0.018	0.001	0.001	0.006	0.017	0.001
28	0.002	0	0.006	0.023	0.001	0	0.002	0.024	0.001
29	0.001	0	0.007	0.021	0.005	0.001	0.022	0.027	0.004
30	0.004	0.002	0	0.03	0.002	0.002	0.024	0.044	0.005
31	0.009	0.001	0.001	0.039	0.002	0.006	0.029	0.027	0.010
32	0.014	0.005	0.007	0.051	0.002	0.008	0.033	0.031	0.014
33	0.016	0.002	0.001	0.043	0.007	0.008	0.026	0.053	0.016
34	0.037	0.018	0.003	0.04	0.003	0.013	0.03	0.008	0.019
35	0.051	0.041	0.001	0.046	0.006	0.015	0.026	0.011	0.021
36	0.07	0.066	0.002	0.053	0.001	0.015	0.042	0.013	0.046
37	0.066	0.1	0.004	0.037	0.009	0.016	0.039	0.043	0.026
38	0.092	0.089	0.006	0.048	0.009	0.019	0.04	0.077	0.052
39	0.129	0.079	0.019	0.051	0.016	0.016	0.059	0.072	0.031
40	0.136	0.108	0.017	0.051	0.036	0.03	0.061	0.066	0.042
41	0.129	0.139	0.077	0.035	0.08	0.035	0.071	0.050	0.046
42	0.101	0.114	0.125	0.044	0.065	0.075	0.06	0.050	0.072
43	0.061	0.109	0.115	0.061	0.127	0.103	0.064	0.065	0.092
44	0.036	0.059	0.153	0.064	0.133	0.114	0.058	0.070	0.101
45	0.021	0.027	0.175	0.073	0.111	0.15	0.083	0.065	0.100
46	0.012	0.018	0.151	0.065	0.113	0.141	0.076	0.062	0.100
47	0.014	0.019	0.104	0.075	0.256	0.231	0.127	0.114	0.189

Table 12-6. Trawl survey age compositions for dusky rockfish in the Gulf of Alaska. Ages 4 and below are pooled. Pooled age 21+ includes all fish 21 and older.

Age (yr)	1984	1987	1990	1993	1996	1999	2001	2003
4	0.000	0.000	0.008	0.004	0.013	0.001	0.014	0.002
5	0.000	0.000	0.005	0.058	0.007	0.001	0.006	0.072
6	0.000	0.000	0.003	0.094	0.014	0.001	0.081	0.114
7	0.067	0.192	0.001	0.193	0.004	0.056	0.074	0.011
8	0.258	0.003	0.001	0.088	0.025	0.013	0.052	0.288
9	0.108	0.047	0.007	0.119	0.049	0.047	0.188	0.073
10	0.142	0.155	0.115	0.031	0.188	0.033	0.095	0.019
11	0.155	0.213	0.134	0.032	0.111	0.113	0.093	0.064
12	0.129	0.109	0.086	0.020	0.148	0.271	0.037	0.037
13	0.058	0.057	0.114	0.048	0.045	0.121	0.066	0.035
14	0.015	0.034	0.171	0.022	0.030	0.065	0.099	0.019
15	0.048	0.043	0.139	0.039	0.033	0.025	0.061	0.044
16	0.007	0.014	0.043	0.045	0.015	0.015	0.034	0.066
17	0.000	0.027	0.015	0.042	0.018	0.001	0.013	0.033
18	0.000	0.012	0.055	0.016	0.052	0.021	0.009	0.016
19	0.000	0.019	0.035	0.016	0.041	0.025	0.007	0.020
20	0.004	0.010	0.009	0.010	0.045	0.048	0.008	0.004
21+	0.010	0.065	0.061	0.123	0.165	0.146	0.062	0.083
Sample size	161	386	145	508	652	184	718	276

Table 12-7. Instantaneous rate of natural mortality and maximum age for pelagic shelf rockfish, based on the break-and-burn method of aging otoliths. Area indicates location of study: Gulf of Alaska (GOA) or British Columbia (BC).

Species	Mortality Rate	Maximum Age	Area	Reference
Dusky Rockfish	0.09	59	GOA	1
	0.09	51	GOA	7
	0.08	59[b]	GOA	5
	0.06	76[c]	GOA	6
Dark Rockfish	0.07	75	GOA	2
Yellowtail Rockfish	0.07	53	BC	3
Widow Rockfish	0.05[a]	59	BC	4

[a] Instantaneous rate of total mortality (Z).
[b] Maximum survey age.
[c] Maximum fishery age.

References: 1) Clausen and Heifetz (1991); 2) Chilton, L. *In Review*. Growth and natural mortality of dark rockfish (*Sebastes ciliatus*) in the western Gulf of Alaska. 23rd. Lowell Wakefield Fisheries Symposium on Biology, Assessment, and Management of North Pacific Rockfishes 3) Leaman and Nagtegaal (1987); 4) Chilton and Beamish (1982); 5) Malecha et al. (2004); 6) Calculated for this document using Hoenig (1983) ($-\ln(0.001)/t_m$); 7) Back-calculated maximum age using Hoenig (1983) ($-\ln(0.001)/M$).

Table 12-8. Likelihoods and estimates of key parameters with estimates of standard error (σ) derived from Hessian matrix for 2 models for GOA dusky rockfish.

	Model 1		***Model 2***	
Likelihoods	Value	Weight	Value	Weight
Catch	0.52	10	15.26	10
Trawl Biomass	31.47	5	31.40	5
Fishery Ages	20.13	1	18.59	1
Survey Ages	60.77	1	61.43	1
Fishery Sizes	69.04	1	57.99	1
Data-Likelihood	**181.929**		**184.657**	
Penalties/Priors				
Recruitment Devs	21.09	1	32.66	1
Fishery Selectivity	1.29	1	1.90	1
Trawl Selectivity	0.71	1	0.83	1
Fish-Sel Domeshape	0.00	1	0.00	1
Survey-Sel Domeshape	0.00	1	0.00	1
Average Selectivity	0.00	1	0.00	1
F Regularity	5.69	0.1	71.68	2
σ_r prior	3.26		0.02	
q-prior	0.10		0.00	
Total (unweighted)	83.75		71.66	
Objective Fun. Total (unweighted)	**265.68**		**256.31**	

Parameter Estimates	Value	σ	Value	σ
q-trawl	0.673	0.175	0.811	0.135
σ_r	1.185	0.135	1.256	0.199
Log-mean-rec	1.238	0.208	0.430	0.204
$F_{40\%}$	0.124	0.026	0.088	0.017
Total Biomass (mt)	64,620	16,507	86,893	25,445
B_{2006} (mt)	23,204		24,733	
$B_{100\%}$ (mt)	41,464		45,727	
$B_{40\%}$ (mt)	16,586		18,291	
$ABC_{F40\%}$ (mt)	5,554		**4,885**	
$F_{50\%}$	0.082	0.016	0.060	0.011
$ABC_{F50\%}$ (mt)	3,702		3,320	

Table 12-9. Set of projections of spawning biomass (SB) and yield for dusky rockfish in the Gulf of Alaska. Six harvest scenarios designed to satisfy the requirements of Amendment 56, NEPA, and MSFCMA. For a description of scenarios see section 12.6.3. All units in mt. $B_{40\%}$ = 18,291 mt, $B_{35\%}$ = 16,004 mt, $F_{40\%}$ = 0.088, and $F_{35\%}$ = 0.108.

Year	Maximum permissible F	Author's F (pre-specified catch)*	Half maximum F	5-year average F	No fishing	Overfished	Approaching overfished
			Spawning Biomass (mt)				
2005	22,956	22,956	22,956	22,956	22,956	22,956	22,956
2006	24,585	24,733	24,742	24,688	24,901	24,515	24,585
2007	25,473	26,342	26,565	26,184	27,713	25,000	25,473
2008	26,142	26,967	28,176	27,457	30,402	25,287	26,062
2009	26,262	27,033	29,329	28,232	32,816	25,007	25,715
2010	25,828	26,540	29,912	28,434	34,730	24,202	24,836
2011	25,098	25,755	30,084	28,258	36,197	23,167	23,726
2012	24,175	24,781	29,895	27,775	37,188	22,022	22,508
2013	23,272	23,833	29,568	27,206	37,915	20,970	21,390
2014	22,387	22,899	29,106	26,556	38,356	19,999	20,356
2015	21,647	22,104	28,692	25,990	38,750	19,227	19,522
2016	21,097	21,496	28,416	25,579	39,233	18,694	18,935
2017	20,592	20,915	28,068	25,138	39,496	18,250	18,443
2018	20,296	20,542	27,925	24,897	39,985	18,008	18,161
			Fishing Mortality				
2005	0.046	0.046	0.046	0.046	0.046	0.046	0.046
2006	0.088	0.047	0.044	0.059	-	0.108	0.088
2007	0.088	0.088	0.044	0.059	-	0.108	0.088
2008	0.088	0.088	0.044	0.059	-	0.108	0.108
2009	0.088	0.088	0.044	0.059	-	0.108	0.108
2010	0.088	0.088	0.044	0.059	-	0.108	0.108
2011	0.088	0.088	0.044	0.059	-	0.108	0.108
2012	0.088	0.088	0.044	0.059	-	0.108	0.108
2013	0.088	0.088	0.044	0.059	-	0.108	0.108
2014	0.088	0.088	0.044	0.059	-	0.107	0.107
2015	0.088	0.088	0.044	0.059	-	0.104	0.105
2016	0.087	0.087	0.044	0.059	-	0.101	0.102
2017	0.086	0.086	0.044	0.059	-	0.099	0.099
2018	0.085	0.085	0.044	0.059	-	0.097	0.098
			Yield (mt)				
2005	2,179	2,179	2,179	2,179	2,179	2,179	2,179
2006	4,885	4,885	2,494	3,326	-	5,927	4,885
2007	4,800	4,979	2,545	3,350	-	5,726	4,800
2008	5,693	5,855	3,096	4,039	-	6,717	6,907
2009	5,764	5,907	3,237	4,176	-	6,704	6,870
2010	5,232	5,358	3,059	3,893	-	5,977	6,120
2011	4,737	4,848	2,879	3,615	-	5,320	5,442
2012	4,336	4,437	2,728	3,385	-	4,797	4,901
2013	4,197	4,302	2,698	3,321	-	4,606	4,694
2014	4,083	4,187	2,672	3,267	-	4,421	4,512
2015	3,975	4,063	2,644	3,213	-	4,197	4,282
2016	3,872	3,975	2,627	3,177	-	4,033	4,104
2017	3,768	3,845	2,610	3,142	-	3,905	3,962
2018	3,690	3,751	2,600	3,118	-	3,825	3,871

*The 2007 ABC was projected using an expected catch value of 2,649 mt for 2006. This estimate is based on recent ratios of catch to maximum permissible ABC. This is in response to management requests for a more accurate one-year projection.

Table 12-10. Allocation of 2005 ABC for pelagic shelf rockfish in the Gulf of Alaska. Apportionment is based on the weighted average of pelagic shelf rockfish assemblage biomass estimates in last three trawl surveys. Allocation for West Yakutat and SE/Outside is equal to the upper 95% confidence interval of the ratio of biomass in West Yakutat area to SE/Outside area.

Year	Weights	Western Gulf	Central Gulf	West Yakutat	SE/ Outside	Total
2001	4	13	56	17	14	100%
2003	6	6	75	16	3	100%
2005	9	46	52	1	1	100%
Weighted Mean		26	60	9	4	100%
Area Allocation						100%
Area ABC Dark, Widow, Yellowtail		**146**	**331**	**30**	**44**	**551**
Area ABC Dusky (mt)		**1,292**	**2,931**	**270**	**391**	**4,885**
Area ABC Total Pelagic Shelf		**1,438**	**3,262**	**301**	**436**	**5,436**
OFL Dark, Widow, Yellowtail (mt)						**735**
OFL Dusky (mt)						**5,927**
OFL Total Pelagic Shelf						**6,662**

Table 12-11. Analysis of ecosystem considerations for pelagic shelf rockfish and the dusky rockfish fishery.

Ecosystem effects on *GOA pelagic shelf rockfish*			
Indicator	Observation	Interpretation	Evaluation
Prey availability or abundance trends			
Phytoplankton and Zooplankton	Important for larval and post-larval survival but no information known	May help determine year class strength, no time series	Possible concern if some information available
Predator population trends			
Marine mammals	Not commonly eaten by marine mammals	No effect	No concern
Birds	Stable, some increasing some decreasing	Affects young-of-year mortality	Probably no concern
Fish (Halibut, arrowtooth, lingcod)	Arrowtooth have increased, others stable	More predation on juvenile rockfish	Possible concern
Changes in habitat quality			
Temperature regime	Higher recruitment after 1977 regime shift	Contributed to rapid stock recovery	No concern
Winter-spring environmental conditions	Affects pre-recruit survival	Different phytoplankton bloom timing	Causes natural variability, rockfish have varying larval release to compensate
Production	Relaxed downwelling in summer brings in nutrients to Gulf shelf	Some years are highly variable like El Nino 1998	Probably no concern, contributes to high variability of rockfish recruitment
GOA pelagic rockfish fishery effects on ecosystem			
Indicator	Observation	Interpretation	Evaluation
Fishery contribution to bycatch			
Prohibited species	Stable, heavily monitored	Minor contribution to mortality	No concern
Forage (including herring, Atka mackerel, cod, and pollock)	Stable, heavily monitored (P. cod most common)	Bycatch levels small relative to forage biomass	No concern
HAPC biota	Medium bycatch levels of sponge and corals	Bycatch levels small relative to total HAPC biota, but can be large in specific areas	Probably no concern
Marine mammals and birds	Very minor take of marine mammals, trawlers overall cause some bird mortality	Rockfish fishery is short compared to other fisheries	No concern
Sensitive non-target species	Likely minor impact on non-target rockfish	Data limited, likely to be harvested in proportion to their abundance	Probably no concern
Fishery concentration in space and time	Duration is short and in patchy areas	Not a major prey species for marine mammals	No concern, fishery is being extended for several months starting 2006
Fishery effects on amount of large size target fish	Depends on highly variable year-class strength	Natural fluctuation	Probably no concern
Fishery contribution to discards and offal production	Decreasing	Improving, but data limited	Possible concern with non-target rockfish
Fishery effects on age-at-maturity and fecundity	Black rockfish show older fish have more viable larvae	Inshore rockfish results may not apply to longer-lived slope rockfish	Definite concern, studies being initiated in 2005

Table 12-12. Nontarget species bycatch estimates in kilograms and proportion of total catch for Gulf of Alaska rockfish targeted fisheries 2003-2005.

	Estimated Catch (kg)			Estimated Proportions		
Group Name	2003	2004	2005	2003	2004	2005
Benthic urochordata	2	130		0.0%	0.0%	0.0%
Birds (fulmar)	215			0.0%	0.0%	0.0%
Bivalves	5			0.0%	0.0%	0.0%
Brittle star unidentified	161	2	47	0.0%	0.0%	0.0%
Corals Bryozoans unidentified	1,903	60	6,125	0.2%	0.0%	1.3%
Red Tree Coral	0	5		0.0%	0.0%	0.0%
Eelpouts	30	222	11,511	0.0%	0.0%	2.5%
Eulachon	11	197	87	0.0%	0.0%	0.0%
Giant Grenadier	139,262	418	134,077	16.1%	0.0%	28.7%
Greenlings	8,372	6,923	3,542	1.0%	0.2%	0.8%
Grenadier Unidentified	480,913	2,835,239	95,760	55.6%	92.2%	20.5%
Hermit crab unidentified	13	10	40	0.0%	0.0%	0.0%
Invertebrate unidentified	441	938	98	0.1%	0.0%	0.0%
Lanternfishes (myctophidae)		0		0.0%	0.0%	0.0%
Large Sculpins	123	42,999	16,478	0.0%	1.4%	3.5%
Misc crabs	28	338	705	0.0%	0.0%	0.2%
Misc crustaceans		24		0.0%	0.0%	0.0%
Misc fish	145,399	116,116	117,559	16.8%	3.8%	25.2%
Octopus	654	425	18	0.1%	0.0%	0.0%
Other osmerids	553	141	15	0.1%	0.0%	0.0%
Other Sculpins	24,076	15,019	14,506	2.8%	0.5%	3.1%
Pandalid shrimp	916	293	261	0.1%	0.0%	0.1%
Polychaete unidentified	4			0.0%	0.0%	0.0%
Scypho jellies	660	2,920	150	0.1%	0.1%	0.0%
Sea anemone unidentified	3,304	2,940	296	0.4%	0.1%	0.1%
Sea pens whips		2	43	0.0%	0.0%	0.0%
Sea star	3,306	2,102	1,468	0.4%	0.1%	0.3%
Shark (other)	199	221	178	0.0%	0.0%	0.0%
pacific sleeper		70	150	0.0%	0.0%	0.0%
salmon	12	120	500	0.0%	0.0%	0.1%
spiny dogfish	1,083	1,249	1,036	0.1%	0.0%	0.2%
Skate (big)		6,635	4,622	0.0%	0.2%	1.0%
Longnose	30	16,270	9,348	0.0%	0.5%	2.0%
Other	39,662	10,380	45,017	4.6%	0.3%	9.6%
Snails	423	302	157	0.0%	0.0%	0.0%
Sponge unidentified	3,815	1,140	1,130	0.4%	0.0%	0.2%
Squid	8,767	11,741	1,458	1.0%	0.4%	0.3%
urchins dollars cucumbers	353	606	160	0.0%	0.0%	0.0%
Grand Total	864,697	3,076,198	466,544	100.0%	100.0%	100.0%
Benthic urochordata	2	130		0.0%	0.0%	0.0%

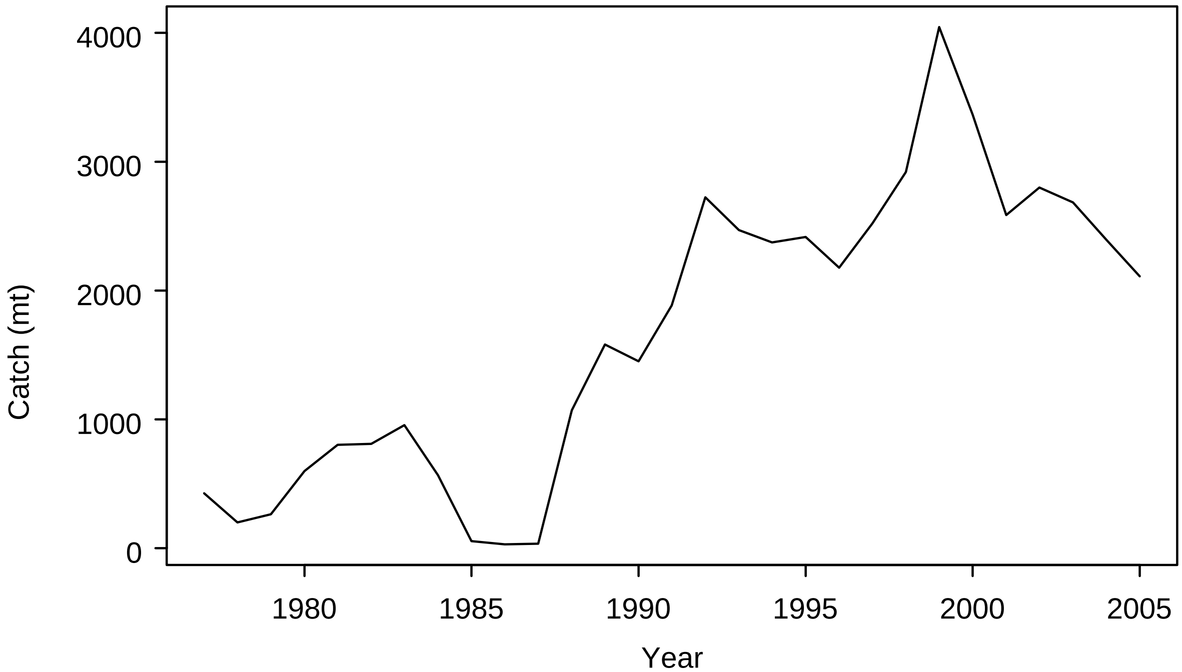

Figure 12-1. Estimated commercial catches for Gulf of Alaska dusky rockfish.

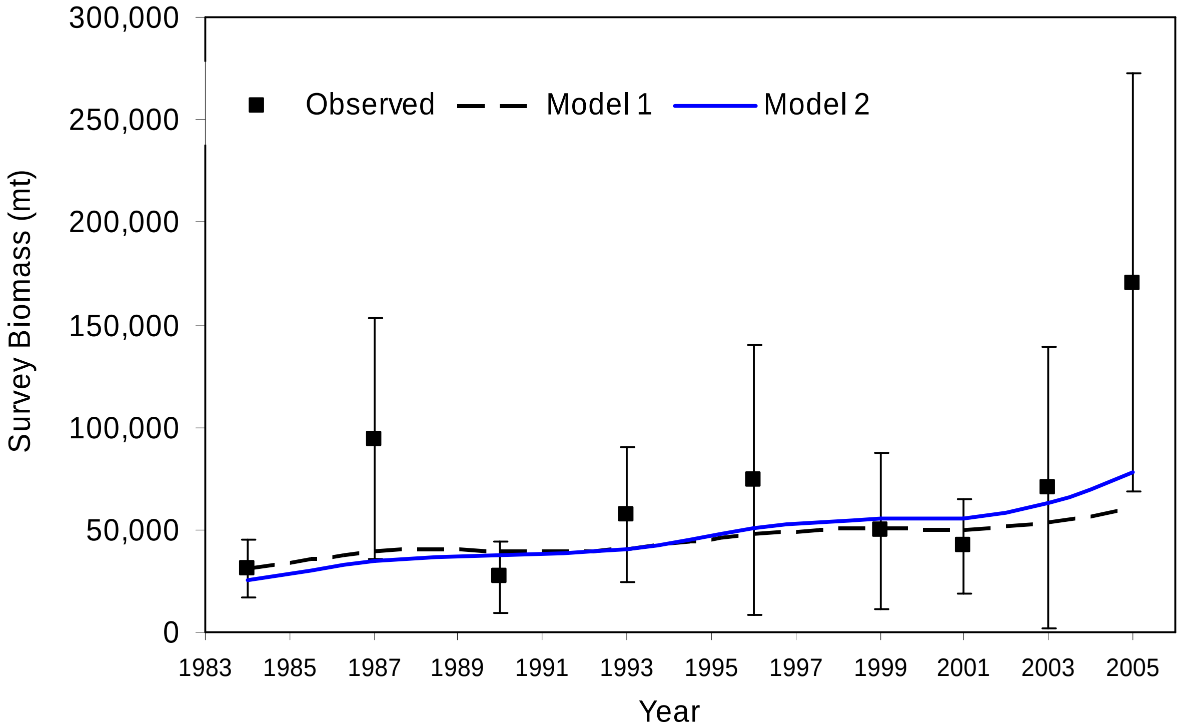

Figure 12-2. Observed and predicted GOA dusky rockfish trawl survey biomass based on the two models. Observed biomass=squares with 95% confidence intervals of sampling error.

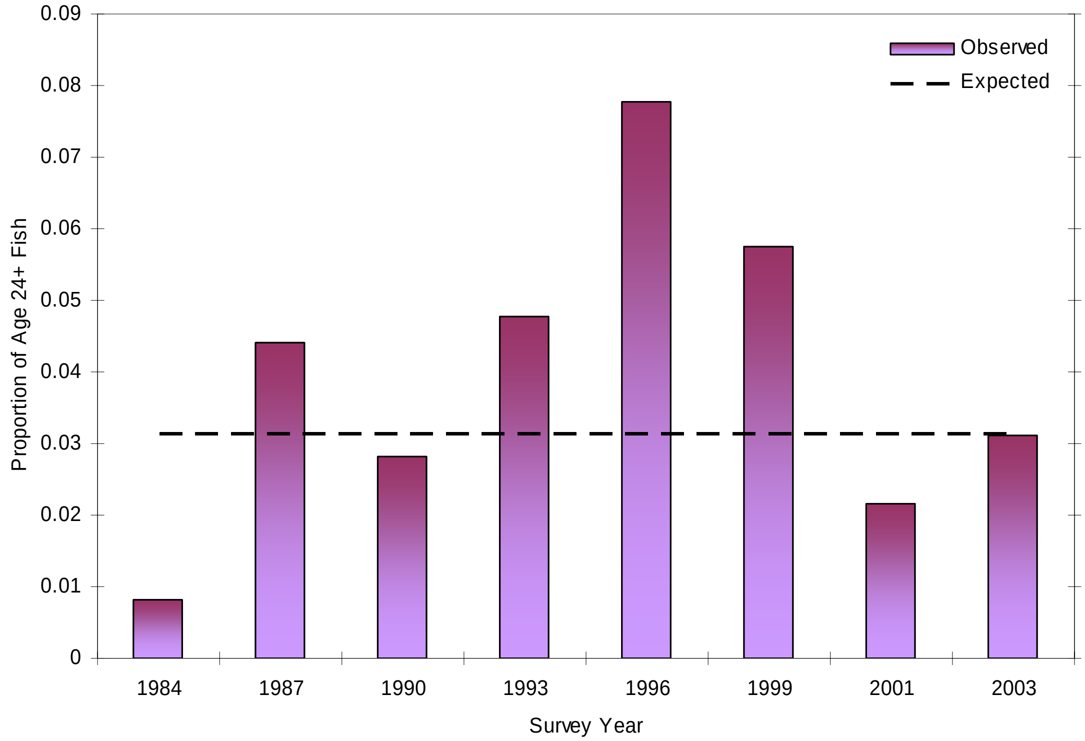

Figure 12-3. Proportion of fish in survey age collections greater than 40% of maximum observed survey age (fish over 24 years old) over time for Gulf of Alaska dusky rockfish.

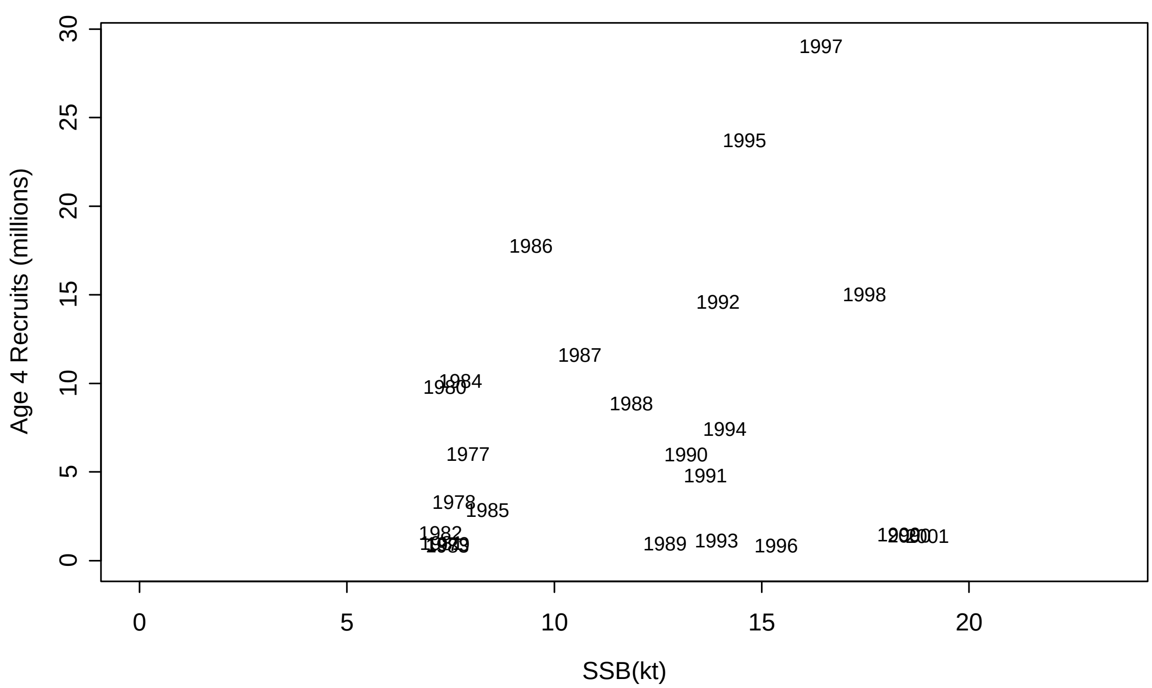

Figure 12-4. Scatterplot of spawner-recruit data for GOA dusky rockfish estimated from Model 2. Label is year class of age 4 recruits. SSB = Spawning stock biomass in kilotons.

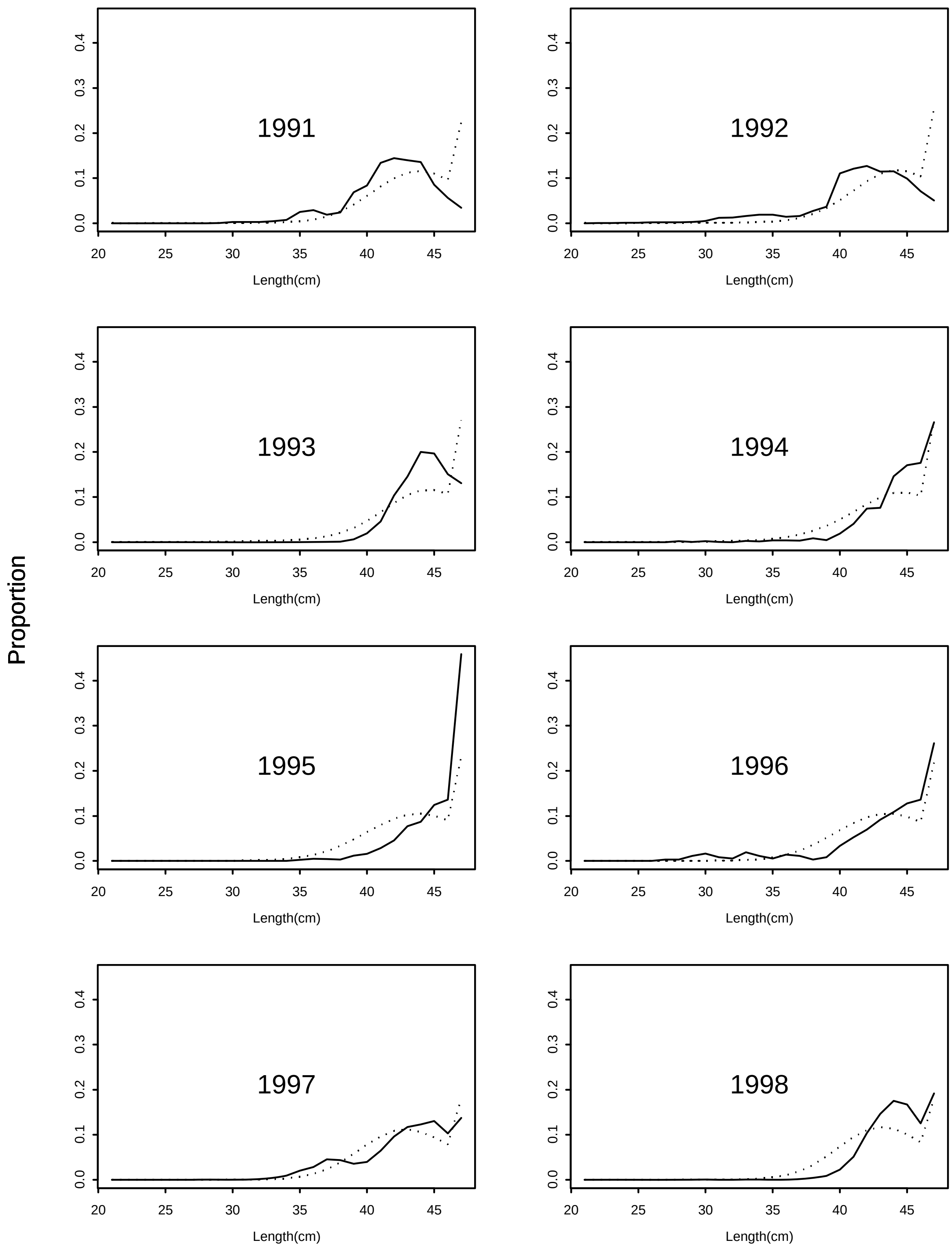

Figure 12-5a. Fishery length compositions for GOA dusky rockfish. Observed=solid line, predicted for Model 2=dotted line.

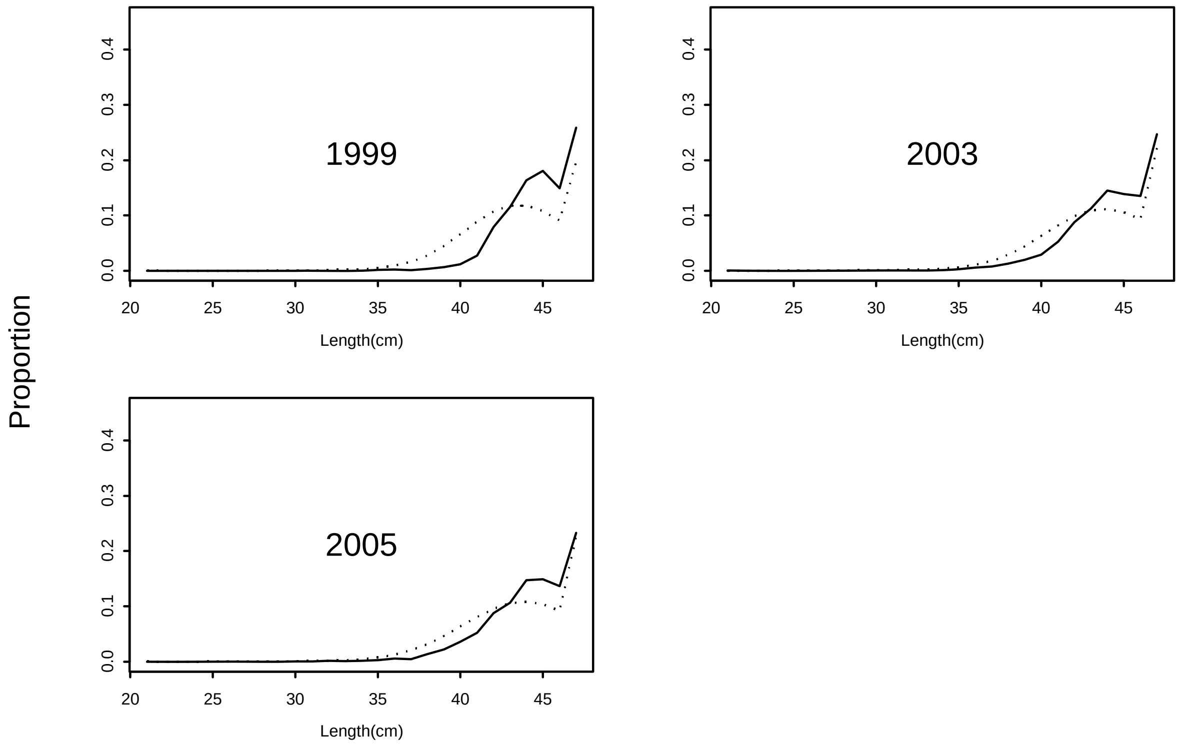

Figure 12-5a (continued). Fishery length compositions for GOA dusky rockfish. Observed=solid line, predicted for Model 2=dotted line.

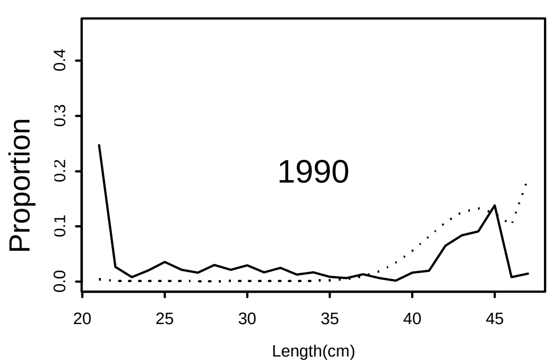

Figure 12-5b. Fishery length compositions for GOA dusky rockfish for 1990. Observed=solid line, predicted for Model 1=dotted line.

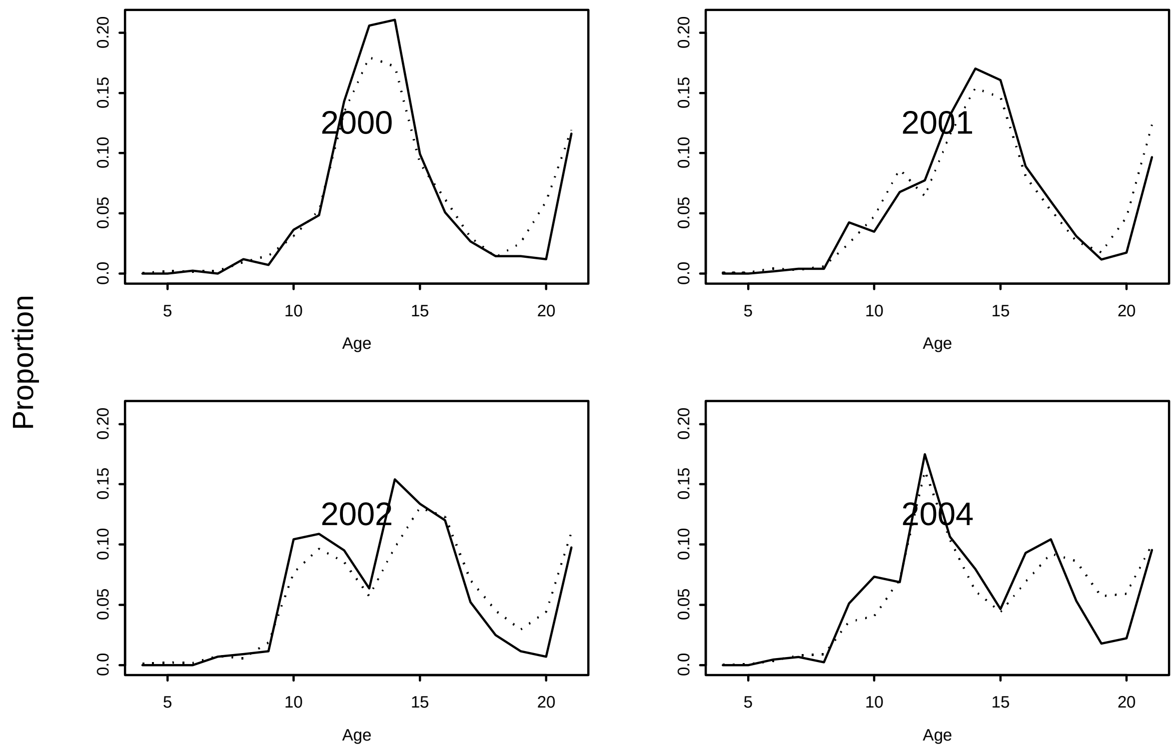

Figure 12-6. Fishery ages for GOA dusky rockfish. Observed=solid line, predicted for Model 2=dotted line.

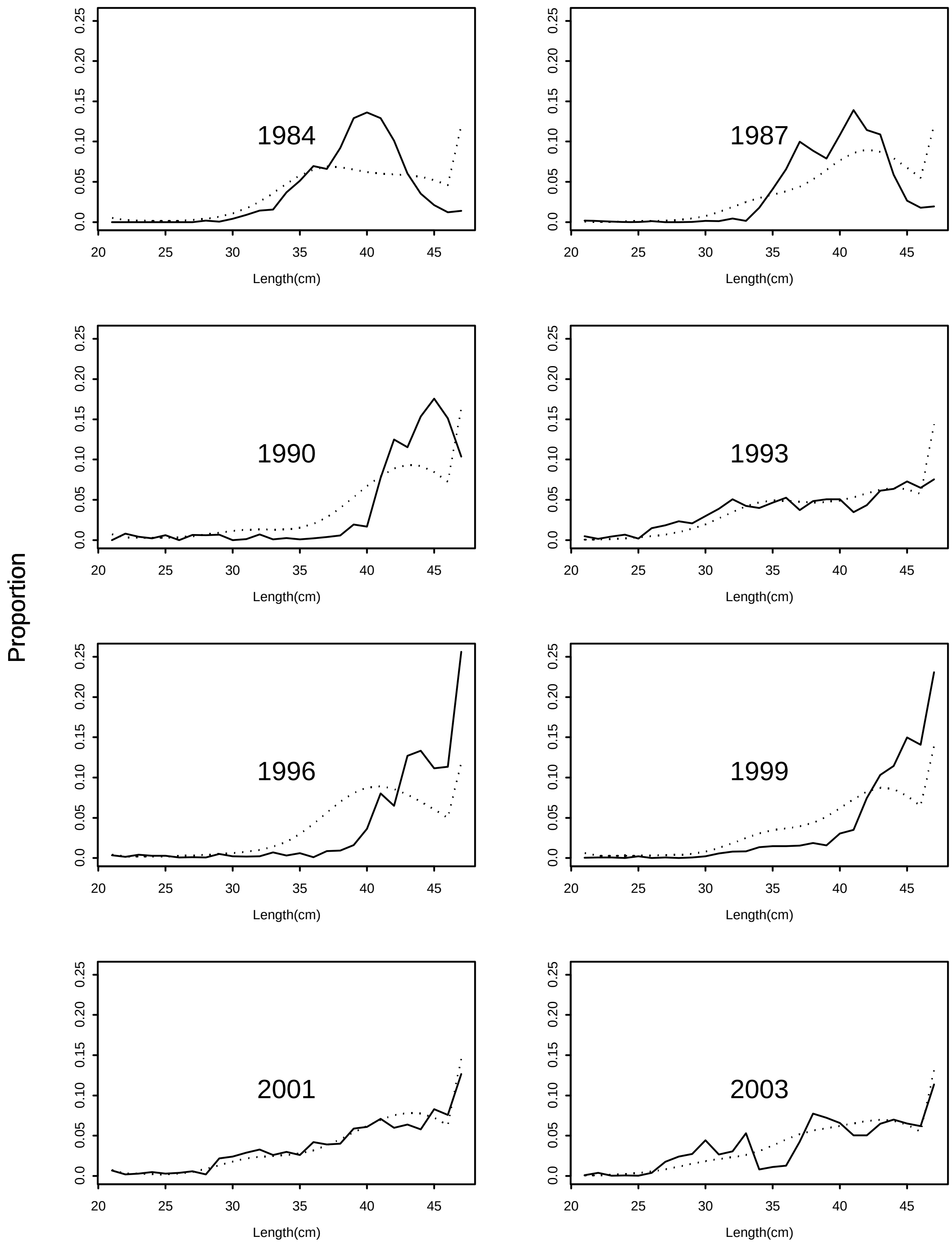

Figure 12-7. Trawl survey size composition by year for GOA dusky rockfish. Observed=solid line, predicted for Model 2=dotted line. Size distributions are not used in the dusky rockfish model because survey ages are available for these years.

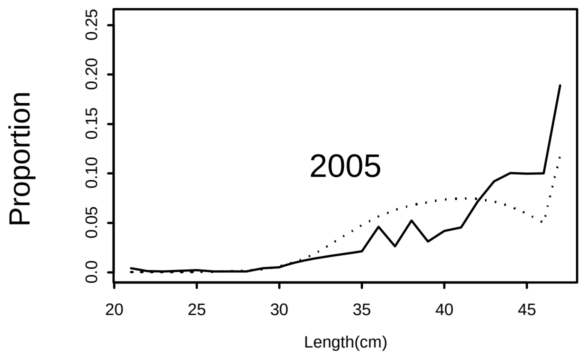

Figure 12-7 (continued). Trawl survey size composition by year for GOA dusky rockfish. Observed=solid line, predicted for Model 2=dotted line. Size distributions are not used in the dusky rockfish model because survey ages are available for these years.

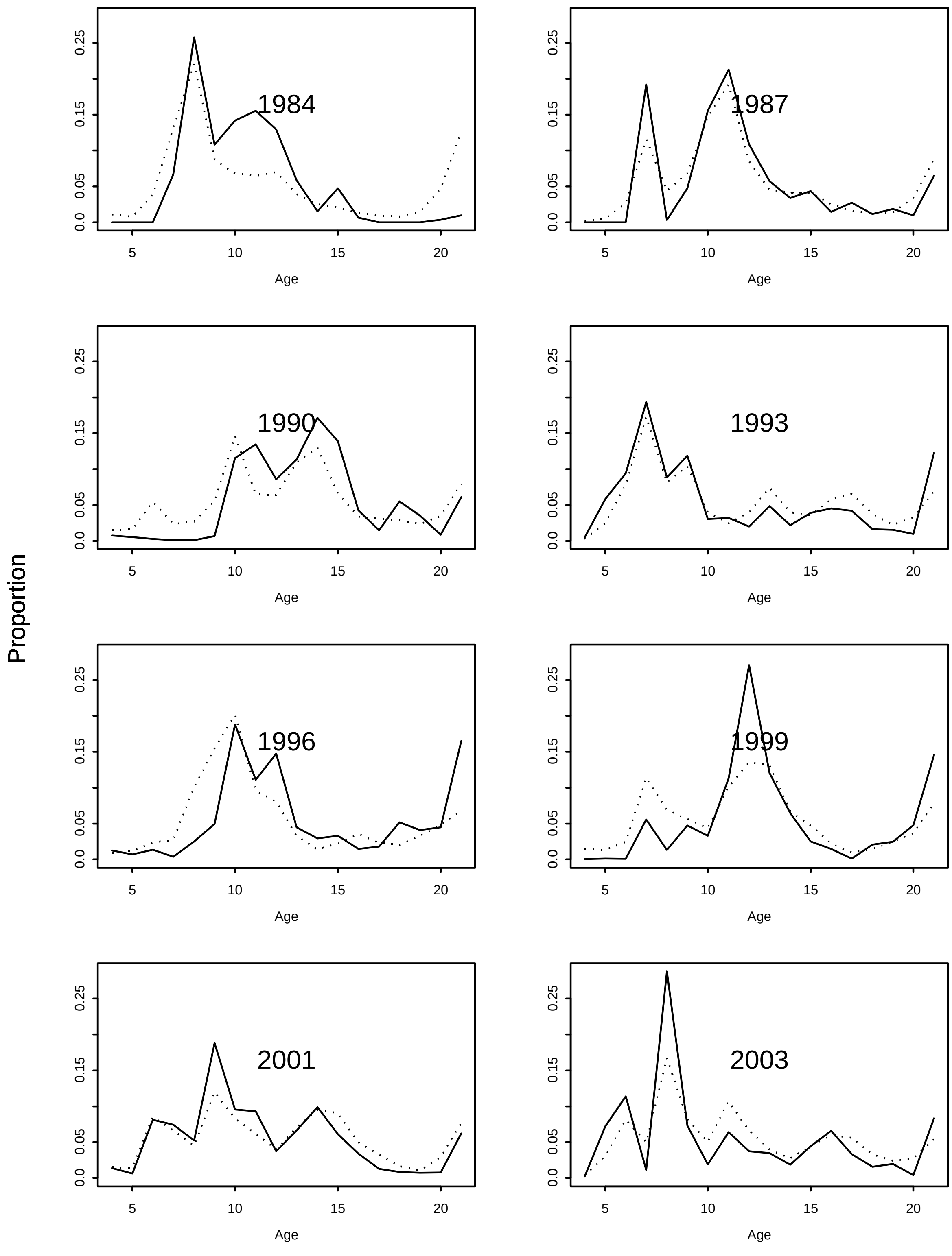

Figure 12-8. Trawl survey age composition by year for GOA dusky rockfish. Observed=solid line, predicted for Model 2=dotted line.

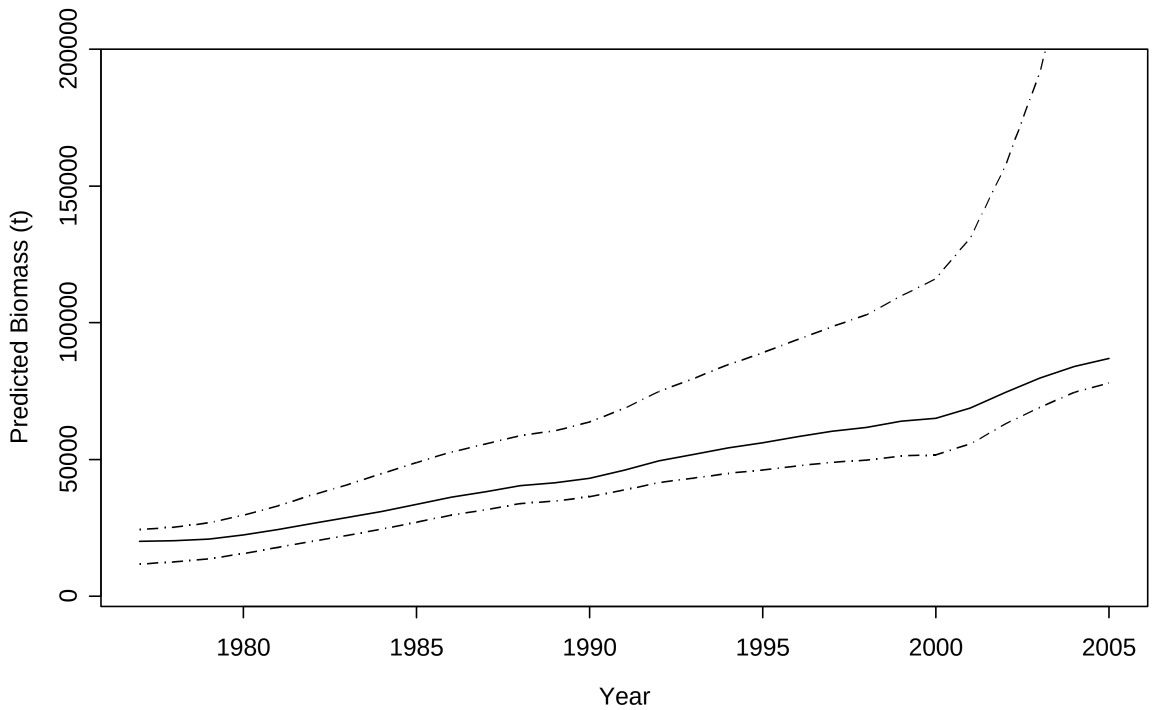

Figure 12-9. Time series of predicted total biomass of GOA dusky rockfish for Model 2. Dashed lines represent 95% confidence intervals from 5 million MCMC runs.

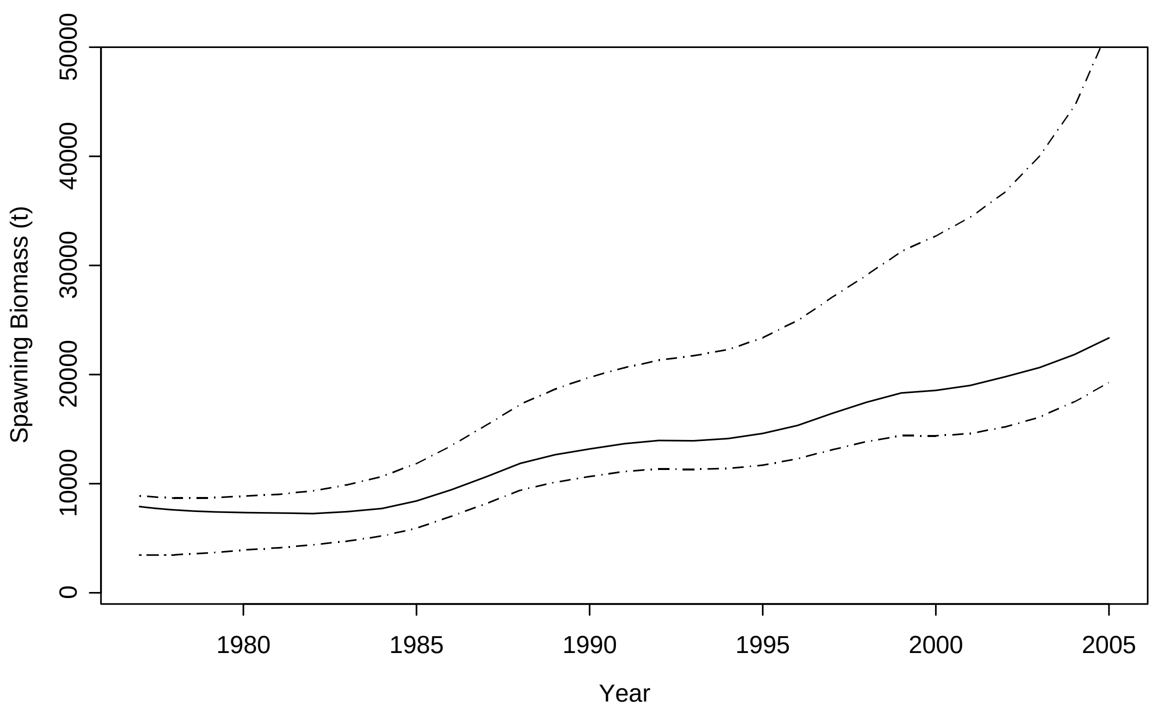

Figure 12-10. Time series of predicted spawning biomass of GOA dusky rockfish for Model 2. Dashed lines represent 95% confidence intervals from 5 million MCMC runs.

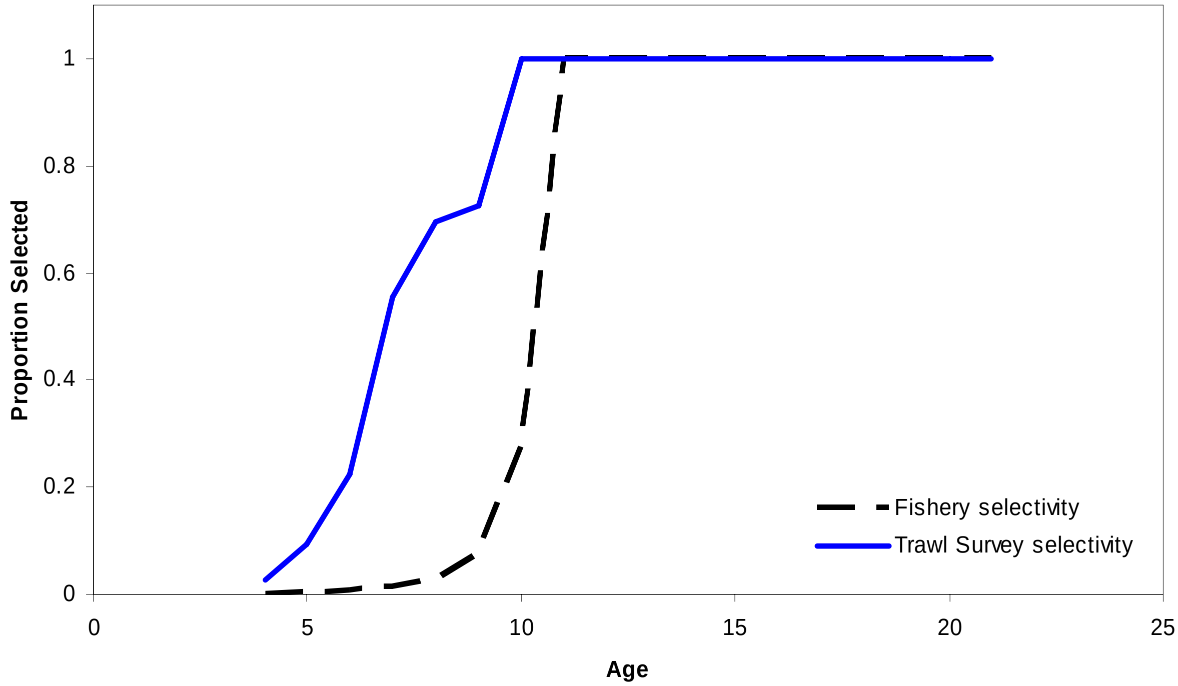

Figure 12-11. Estimated fishery and survey selectivity for Model 2 for GOA dusky rockfish. Dashed line is fishery selectivity and solid line is survey selectivity.

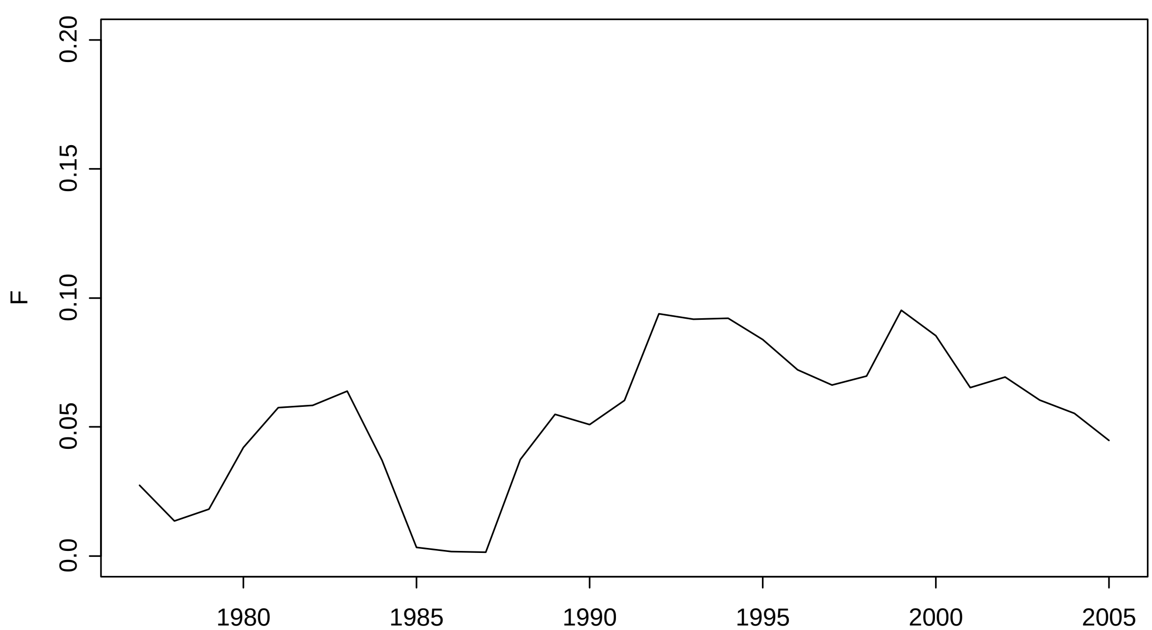

Figure 12-12. Time series of estimated fully selected fishing mortality for GOA dusky rockfish from Model 2.

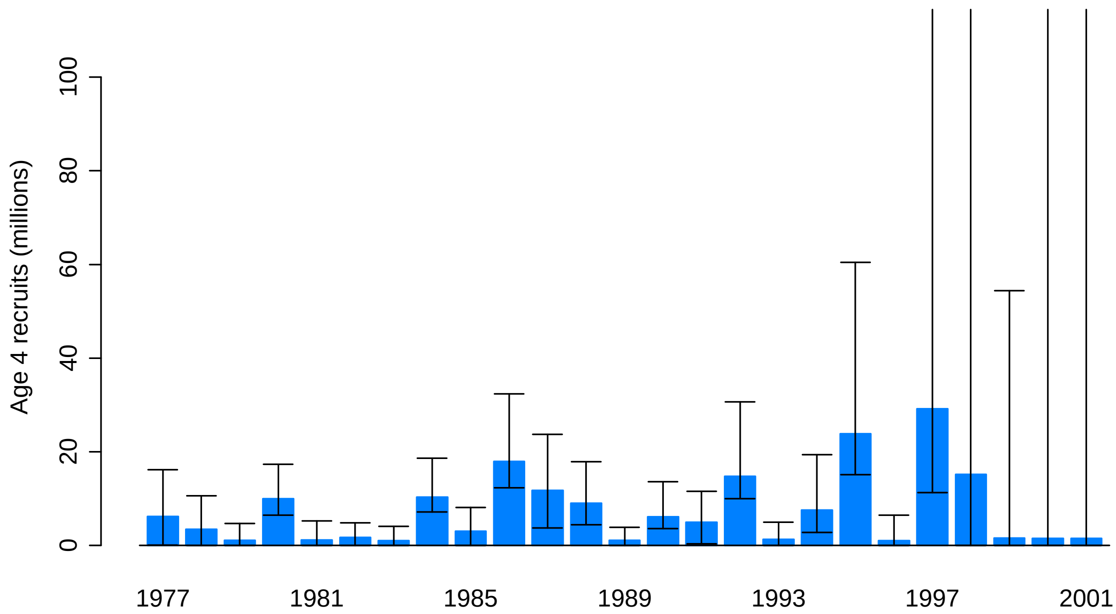

Figure 12-13. Estimated recruitments (age 4) for GOA dusky rockfish from Model 2.

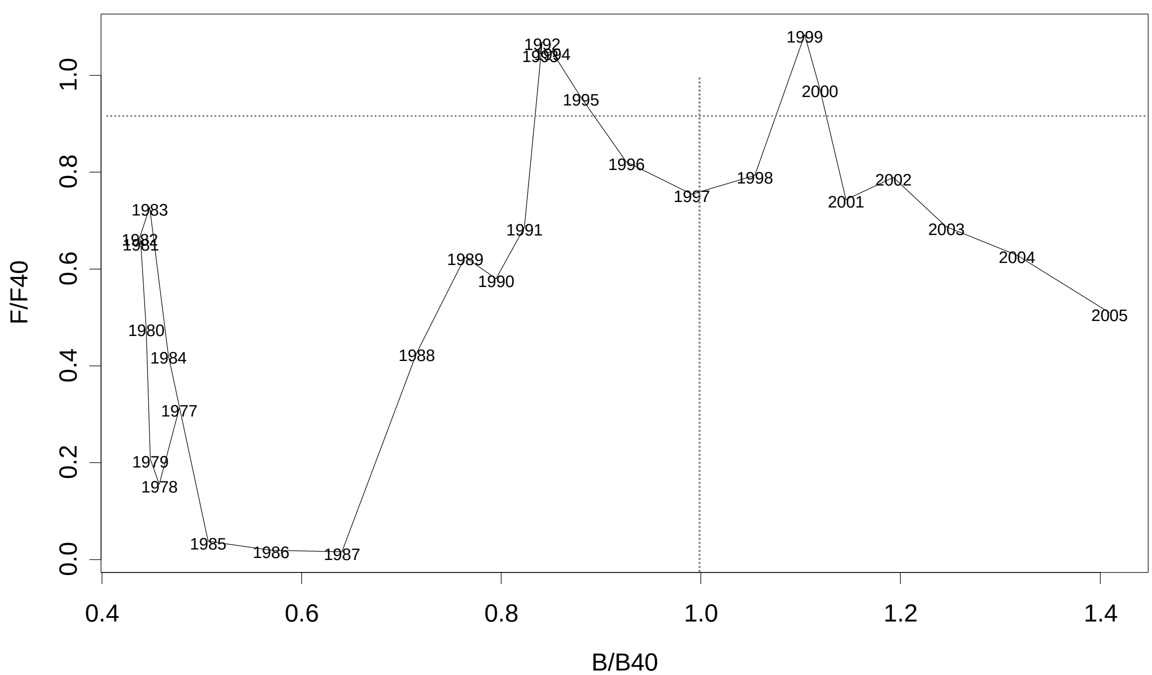

Figure 12-14. Time series of estimated fishing mortality over $F_{40\%}$ versus estimated spawning biomass over $B_{40\%}$ of GOA dusky rockfish for Model 2.